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ECOLEBAN

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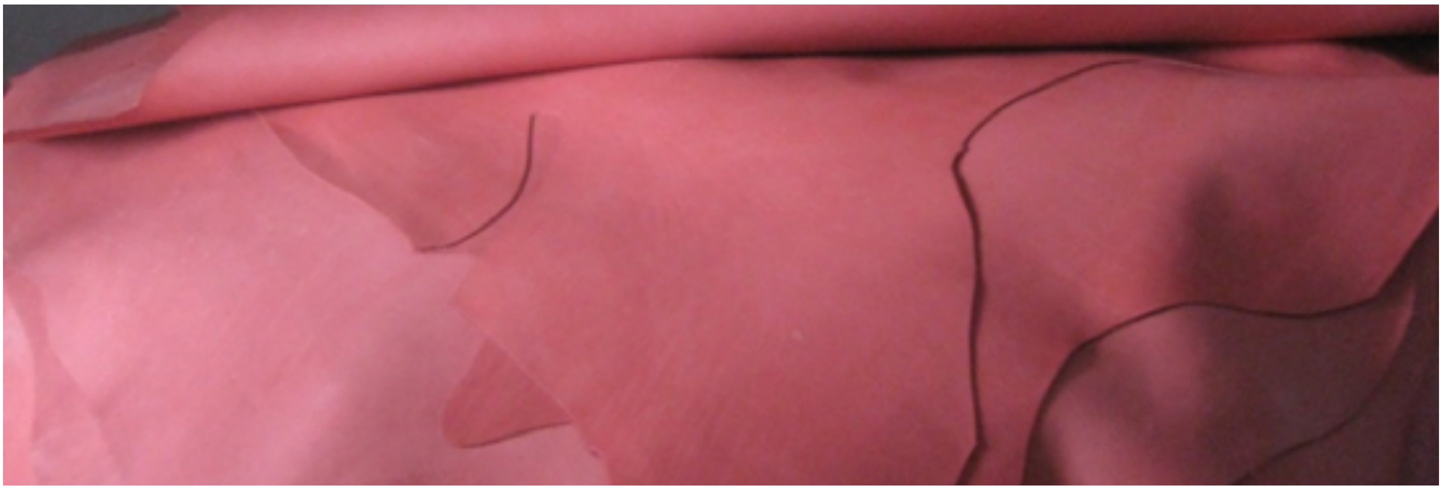
Guidelines on best Sustainable Consumption and Production (SCP) practices for the leather sector in Bangladesh



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switchasia PROGRAMME

Guidelines on best Sustainable Consumption and Production (SCP) practices for the leather sector in Bangladesh

Implementation of Environmental Management Systems (EMS) and eco-labelling schemes in the SMEs of the leather sector in Bangladesh (ECOLEBAN) is a project co-funded by the European Comission under the SWITCH Asia Programme and implemented by the project partners: Fundación Tecnalia Research & Innovation (Tecnalia), Bangladesh Tanners Association (BTA), Bangladesh Finished Leather, Leathergoods and Footwear Exporters' Association (BFLLFEA) and Leathergoods & Footwear Manufacturers & Exporters Association of Bangladesh (LFMEAB).

INKOA SISTEMAS has participated in the elaboration of these guidelines, providing technical support to the project partners.

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1 GLOSSARY

AOX – Adsorbable organic halides
BOD – Biochemical Oxygen Demand
BSP – Best Sustainable Practice
COD – Chemical Oxygen Demand
EDTA – ethylenediaminetetraacetatic acid
EMS – Environmental Management System
EoL – End of life
EPB – Export Promotion Bureau
GDP – Gross Domestic Product
HEM – High-efficiency motors
HVLP – High Volume Low Pressure
LCA – Life Cycle Assessment
LED – Light-emitting Diode
LTD - Low-temperature Drying
NF - Nanofiltration
NPE – Nonylphenol ethoxylate
NTA - Nitrilotriacetic acid
OIT – 2-n-octylisothiazolin-3-one
OPP – ortho-phenylphenol
PCMC – para-chloro-meta-cresol
PCP – pentachlorophenol
PFOA – perfluorooctanoic acid
PFOS – perfluorooctane sulphonate
PI – Process Improvements
PMA – phenylmercuric acetate
PVC – polyvinyl chloride
REACH – Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals
SCP – Sustainable Consumption and Production
SMC – Sheet Moulding Compound
SME – Small and medium-sized enterprise
SS – Suspended Solids
TCMTB – 2-(thiocyanomethylthio)benzothiazole
TKN – Total Kjeldahl Nitrogen
TPE – Thermoplastic elastomer
UF - Ultrafiltration
VFD – Variable Frequency Drive
VOC - Volatile Organic Compounds

2 ENVIRONMENTAL AND ECONOMIC ASSESSMENT

BEST SUSTAINABLE PRACTICES	ENVIRONMENTAL ASSESSMENT	ECONOMIC ASSESSMENT
	✿	$
BSP 1 – GENERAL PRACTICES		
BSP 1.1 – ENVIRONMENTAL MANAGEMENT SYSTEMS	✿✿✿✿✿	$$$
BSP 1.2 – GOOD HOUSEKEEPING	✿✿✿	$
BSP 1.3 - NOISE AND VIBRATION CONTROL	✿	$
BSP 1.4 – MONITORING	✿✿✿	$$$
BSP 1.5 – DECOMMISSIONING	✿✿✿	$$$$
BSP 2 – ENERGY CONSERVATION		
BSP 2.1 – ENERGY MANAGEMENT PROGRAMMES	✿✿✿	$$
BSP 2.2 – ENERGY EFFICIENCY	✿✿✿✿	$$$
BSP 2.3 – REDUCING ELECTRICAL CONSUMPTION BY INTRODUCING THE POWER FACTOR	✿✿✿	$
BSP 2.4 – SOLAR COLLECTOR INSTALLED IN TANNERY	✿✿	$$$$
BSP 3 – SUBSTITUTION OF SUBSTANCES		
BSP 3.1 - SUBSTITUTION OF OCTYLPHENOL AND NONYLPHENOL ETHOXYLATES	✿✿✿	$$
BSP 3.2 - SUBSTITUTION OF HALOGENATED ORGANIC COMPOUNDS IN DEGREASING	✿✿✿	$$
BSP 3.3 - SUBSTITUTION OF HALOGENATED ORGANIC COMPOUNDS IN FATLIQUORS	✿✿✿	$$
BSP 3.3 - SUBSTITUTION OF HALOGENATED ORGANIC COMPOUNDS IN FATLIQUORS	✿✿✿	$$
BSP 3.4 - SUBSTITUTION OR OPTIMISATION OF HALOGENATED ORGANIC COMPOUNDS IN WATER-, SOIL- AND OIL-REPELLENT AGENTS	✿✿✿	$$
BSP 3.5 - SUBSTITUTION OF HALOGENATED ORGANIC COMPOUNDS IN FLAME RETARDANTS	✿✿✿	$$
BSP 3.6 - ELIMINATING PESTICIDES FROM THE RAW MATERIAL (HIDES/SKINS)	✿✿✿	$$
BSP 3.7 – USE OF APPROVED BIOCIDES	✿✿✿	$$
BSP 3.8 - SUBSTITUTION OF COMPLEXING AGENTS	✿✿✿	$$
BSP 3.9 – USE OF APPROVED DYES	✿✿✿	$$
BSP 3.10 – FORBIDDEN SUBSTANCES	✿✿✿	$$
BSP 4 – WASTE WATER		
BSP 4.1 – PROCESS WATER MANAGEMENT	✿✿✿✿	$$$
BSP 4.2 – INDUSTRIAL PROCESS WASTE WATER	✿✿✿✿	$$$
BSP 4.3 – COD/BOD AND SUSPENDED SOLIDS	✿✿✿	$$
BSP 4.4 – SALTS AND TOTAL DISSOLVED SOLIDS	✿✿✿✿	$$
BSP 4.5 – SULPHIDES	✿✿✿	$$
BSP 4.6 – NITROGEN COMPOUNDS	✿✿✿	$$
BSP 4.7 – CHROMIUM AND OTHER TANNING AGENTS	✿✿✿✿	$$
BSP 4.8 – POST-TANNING CHEMICALS	✿✿✿	$$
BSP 4.9 – BIOCIDES	✿✿✿✿	$$
BSP 4.10 – RAINWATER MANAGEMENT	✿✿	$

BSP 5 – AIR EMISSIONS		
BSP 5.1 – ORGANIC SOLVENTS	✿✿✿✿	💰💰
BSP 5.2 – SULPHIDES	✿✿✿	💰💰
BSP 5.3 – AMMONIA	✿✿✿	💰💰
BSP 5.4 – DUST – PARTICULATE MATTER	✿✿	💰💰
BSP 5.5 – ODOURS	✿	💰💰
BSP 6 – WASTE MANAGEMENT		
BSP 6.1 – WASTE MANAGEMENT PLANNING	✿✿✿	💰
BSP 6.2 – WASTE PREVENTION	✿✿✿	💰
BSP 6.3 – RECYCLING AND REUSE	✿✿	💰
BSP 6.3.1 - DUSTED SALTS	✿✿	💰
BSP 6.3.2 - HAIR AND WOOL USE/DISPOSAL	✿✿	💰
BSP 6.3.3 - TRIMMINGS	✿✿	💰
BSP 6.3.4 - FLESHINGS	✿✿	💰
BSP 6.3.5 - SPLITS	✿✿	💰
BSP 6.3.6 - SHAVINGS	✿✿	💰
BSP 6.3.7 - DUST FROM MECHANICAL FINISHING	✿✿	💰
BSP 6.3.8 - FATS, GREASE AND OIL	✿✿	💰
BSP 6.3.9 - DISPOSAL OF EFFLUENT PLANT WASTE	✿✿✿✿	💰💰💰💰
BSP 6.3.10 - DISPOSAL OF OTHER RESIDUES	✿✿✿✿	💰
BSP 6.4 – TREATMENT AND DISPOSAL	✿✿✿✿	💰💰
BSP 6.5 – HAZARDOUS WASTE MANAGEMENT	✿✿✿✿	💰💰💰
BSP 6.6 – WASTE MANAGEMENT IN FOOTWEAR MANUFACTURING	✿✿	💰💰
BSP 7 – OCCUPATIONAL HEALTH AND SAFETY		
BSP 7.1- SAFETY INFORMATION ON CHEMICALS	✿✿	💰
BSP 7.2- CONTROL OF CHEMICAL HAZARDS	✿✿	💰
BSP 7.3 - SAFE CHEMICAL STORAGE	✿✿	💰
BSP 7.4 - SAFE CHEMICAL HANDLING	✿✿	💰
BSP 7.5 - DISPOSAL OF CHEMICAL WASTE AND PACKING MATERIALS	✿✿	💰
BSP 7.6 - OCCUPATIONAL HEALTH AND SAFETY REGARDING BIOLO-GICAL HAZARDS IN TANNERIES	✿✿	💰
BSP 7.7 – EMERGENCY PREPAREDNESS AND RESPONSE	✿✿	💰

PROCESS IMPROVEMENTS	ENVIRONMENTAL ASSESSMENT	ECONOMIC ASSESSMENT
	✿	$
TANNERIES		
PI 1 - BEAMHOUSE		
PI 1.1 - CURING AND SOAKING		
PI 1.1.1 - COOLING AND PROCESSING OF FRESH HIDES AND SKINS	✿✿✿	$
PI 1.1.2 – USE OF ANTISEPTICS	✿✿	$
PI 1.1.3 - USE OF CLEAN HIDES AND SKINS	✿✿✿	$
PI 1.1.4 - REMOVAL OF SALT	✿✿✿	$
PI 1.1.5 – REUSE OF TREATED WASTE WATER IN SOAKING AND LIMING PROCESSES	✿✿	$$$
PI 1.2 - FLESHING		
PI 1.2.1 – GREEN FLESHING	✿✿	$
PI 1.3 - UNHAIRING AND LIMING		
PI 1.3.1 - HAIR-SAVE TECHNIQUES	✿✿	$
PI 1.3.2 - REDUCING SULPHIDE CONSUMPTION (LOW-SULPHIDE UNHAIRING)	✿✿✿	$
PI 1.3.3 - PREVENTION OF H2S EMISSIONS FROM EFFLUENTS	✿✿	$
PI 1.3.4 – DIRECT RECYCLING OF LIMING FLOAT	✿✿	$
PI 1.4 - SPLITTING		
PI 1.4.1 - LIME SPLITTING	✿✿	$
PI 1.5 - DELIMING AND BATING		
PI 1.5.1 - SUBSTITUTION OF AMMONIUM COMPOUNDS BY CO_2	✿✿	$
PI 1.5.2 - SUBSTITUTION OF AMMONIUM COMPOUNDS BY ORGANIC ACIDS	✿✿	$
PI 2 - TANYARD OPERATIONS		
PI 2.1 - PICKLING		
PI 2.1.1 - SALT-FREE AND REDUCED-SALT PICKLING	✿✿✿	$
PI 2.1.2 - OPTIMISING THE USE OF ORGANIC SOLVENTS IN THE DRY DEGREASING OF SHEEPSKINS	✿✿✿	$
PI 2.2 - TANNING		
PI 2.2.1 - INCREASING THE EFFICIENCY OF CHROMIUM TANNING	✿✿✿	$
PI 2.2.2 - HIGH-EXHAUSTION CHROMIUM TANNING	✿✿✿	$$
PI 2.2.3 - RECYCLING AND REUSE OF CHROMIUM SOLUTIONS	✿✿✿	$$
PI 2.2.4 - CHROMIUM RECOVERY THROUGH PRECIPITATION AND SEPARATION	✿✿✿	$$$
PI 2.2.5 - PRETANNING WITH NON-CHROME TANNING AGENTS	✿✿✿	$$
PI 2.2.6 - PRETANNING USING ALDEHYDES, PRODUCING CHROMIUM-FREE LEATHER	✿✿✿	$$
PI 2.2.7 - PRETANNING FOLLOWED BY VEGETABLE TANNING WITH HIGH UPTAKE OF TANNING AGENTS	✿✿✿	$$

PI 3 - POST-TANNING OPERATIONS		
PI 3.1 - PROCESS CHANGES TO REDUCE METAL DISCHARGES	✿✿	$$$
PI 3.2 - OPTIMISED RETANNING	✿✿	$
PI 3.3 - OPTIMISED DYEING	✿✿	$
PI 3.4 - OPTIMISED FATLIQUORING	✿✿	$
PI 3.5 - SUBSTITUTION OF NITROGENOUS COMPOUNDS IN POST-TANNING	✿✿	$$
PI 3.6 - USE OF LIQUID AND LOW-DUST DYES	✿✿	$$
PI 3.7 - DRYING	✿✿	$$
PI 3.8 – METAL-FREE TANNING/DYEING	✿✿	$$
PI 4 - COATING		
PI 4.1 - CASTING/CURTAIN COATING	✿✿	$$
PI 4.2 - ROLLER COATING	✿✿	$$
PI 4.3 - IMPROVED TECHNIQUES FOR SPRAY COATING	✿✿	$$
PI 4.4 - WATER-BASED FINISHING	✿✿	$$
PI 4.5 – BINDERS WITH LOW CONTENT AS FINISHING AGENTS	✿✿	$$
PI 4.6 – HAND PADDING IS BETTER THAN SPRAYING	✿✿	$$
PI 5 – OTHERS		
PI 5.1 - ENERGY		
PI 5.1.1 – USE OF SHORT FLOATS	✿✿✿	$$
PI 5.1.2 – ENERGY RECOVERY FROM PROCESS FLUIDS	✿✿✿	$$
PI 5.1.3 – IMPROVED DRYING TECHNIQUES	✿✿✿	$
PI 5.1.4 – ENERGY RECOVERY FROM WASTE BY DIGESTION	✿✿✿	$$$
PI 5.1.5 – ENERGY RECOVERY FROM WASTE BY COMBUSTION	✿✿✿	$$$
PI 5.2 - WASTE WATER TREATMENT		
PI 5.2.1 - MECHANICAL TREATMENT	✿✿✿✿	$$$$
PI 5.2.2 - PHYSICO-CHEMICAL TREATMENT	✿✿✿✿	$$$$
PI 5.2.3 - BIOLOGICAL TREATMENT	✿✿✿✿	$$$$
PI 5.2.4 - POST-PURIFICATION TREATMENTS AND SLUDGE HANDLING	✿✿✿✿	$$$$
PI 5.2.5 - SEWERS ADAPTED FOR TANNERY EFFLUENTS	✿✿✿✿	$$$$
PI 5.3 - AIR EMISSIONS ABATEMENT		
PI 5.3.1 - ODOUR	✿✿	$$
PI 5.3.2 - ORGANIC SOLVENTS	✿✿✿	$$
PI 5.3.3 - AMMONIA AND HYDROGEN SULPHIDE	✿✿	$$
PI 5.3.4 - DUST AND OTHER PARTICULATES	✿✿	$$

LEATHER MANUFACTURING

PI 6 DESIGN / PRODUCT DEVELOPMENT		
PI 6.1 – ENVIRONMENTALLY FRIENDLY DESIGN	✿✿✿✿	💰💰
PI 7 PRODUCTION		
PI 7.1 CUTTING/CLICKING		
PI 7.1.1 – CUTTING BY PROPER NESTING	✿✿	💰
PI 7.1.2 – REUSE OF POLYMERS FOR SOLE MANUFACTURING	✿✿	💰
PI 7.2 STITCHING/ASSEMBLY		
PI 7.2.1 – POOR FOLLOW-UP DESIGN SPECIFICATION IN STITCHING DEPARTMENT	✿✿	💰
PI 7.2.2 – MINIMISATION OF TOLUENE-BASED ADHESIVE	✿✿✿✿	💰💰
PI 7.2.3 – ASSEMBLY OPTIMISATION	✿	💰
PI 7.3 LASTING		
PI 7.3.1 – PROPER MAINTAINING OF PRODUCTION PARAMETERS	✿	💰
PI 8 PRODUCT FINISHING		
PI 8.1 – PROPER APPLICATION AND DISPOSAL OF FINISHING CHEMICALS	✿✿	💰
PI 8.2 – REUSING AND RECYCLING SOLID WASTE	✿✿	💰
PI 9 FULL PRODUCT PACKAGING		
PI 9.1 – MINIMUM MOISTURE CONTENT	✿✿	💰
PI 9.2 – PACKAGING MATERIALS	✿✿	💰
PI 10 END OF LIFE		
PI 10.1 – RECYCLING	✿✿✿	💰💰
PI 10.2 – ENERGY RECOVERY FROM WASTE	✿✿	💰💰💰
PI 10.3 – END-OF-LIFE MANAGEMENT OPTIONS FOR BIODEGRADABLE MATERIALS	✿✿✿	💰💰

3 INTRODUCTION

ECOLEBAN Project

The ECOLEBAN Project (Implementation of Environmental Management Systems and eco-labelling schemes in the SMEs of the leather sector in Bangladesh), funded by the European Commission under the Switch Asia Programme, is being implemented by Fundación Tecnalia Research & Innovation (TECNALIA, Spain, beneficiary), Bangladesh Finished Leather, Leathergoods and Footwear Exporters Association (BFLLFEA, Bangladesh, partner), Bangladesh Tanners Association (BTA, Bangladesh, partner) and Leathergoods & Footwear Manufacturers & Exporters Association of Bangladesh (LFMEAB, Bangladesh, partner).

The action has an overall duration of 48 months and aims at enhancing the resource efficiency and sustainability of the leather sector in Bangladesh throughout the whole value chain of the leather-related products, such as footwear and other leather goods. Its specific objective is to increase the number of less polluting and more resource efficient leather products by means of the implementation of Environmental Management Systems (EMS) (ISO 14001) and life cycle approaches (LCA, Eco-design) in the SMEs, and promoting 'green' commercialisation and consumption through the use of Eco-labelling.

This deliverable D 1.1-II Guidelines on best Sustainable Consumption and Production (SCP) practices for the leather sector in Bangladesh is a public document developed in the context of Result 1 – Improved sustainability and resource efficiency of the leather sector in Bangladesh throughout the whole value chain.

Leather industry in Bangladesh

The leather sector in Bangladesh is well established and is contributing significantly to the GDP. According to the Bangladesh Export Promotion Bureau (EPB), the contribution of the leather sector to the total GDP was 0.24% in 2010. Furthermore, the leather sector accounts for 9% of total export earnings. In this sense, the leather industry is a big contributor in foreign exchange earnings for the country. In fact, leathers are exported from Bangladesh to about 53 countries of the world. The major importing countries are Hong Kong, Italy, Korea, Japan, USA, Canada, UK, Brazil, Germany, China, etc.

The leather sector is also a major employer of semi-skilled workers, which is a vital step towards alleviating unemployment. Information obtained from a number of credible sources shows that in total 741,000 people are employed directly or indirectly in the leather industry and its subsectors.

Main environmental impacts

In the course of processing hides into leather, about 20% of the material ends up as solid waste: leather scraps, hair, soluble proteins, curing salts and fleshing (animal fats, collagen fibres, meat etc.). This solid waste is usually dumped improperly inside and around the factory area. Tanneries and leather product manufacturing units are generating large amounts of solid waste in the form of leather shavings/cuttings which, used as cheap fuel in the brick kilns, are causing air pollution along with the release of chromium into the environment. Animal feeds prepared from chromium-containing proteins from the solid waste of tanneries are likely to cause direct chromium entry into the food chain.

The effluents discharged are large in volume, are highly coloured and contain heavy sediment load, toxic metallic compounds, chemicals, biologically oxidisable materials and large quantities of putrefying suspended matter. Large pH fluctuation and high BOD value caused by tannery effluents can kill all natural life in an affected water body. Hydrogen sulphide formed due to the presence of sulphide in the effluent is highly toxic to many forms of life. Another toxic pollutant of great concern present in tannery effluents is chromium, which is known to cause perforations and bronchogenic carcinoma to continuously exposed humans.

Guidelines

The content of this document has been structured as follows:

- **Objective and methodology -** This section describes the aim of the guidelines, the target audience, the relevance of applying SCP practices and avoiding traditional polluting practices, the procedure followed in the preparation of the guidelines, the information sources, etc.

- **Environmental hotspots and constraints of the Bangladeshi leather sector -** in this section the main environmental impacts are described and the hotspots of the value chain are identified. In addition, the problems and constraints that should be faced for the Bangladeshi leather industry to be more sustainable are assessed.

- **Best Sustainable Practices (BSPs) -** in this section the best sustainable practices are described. These practices aim to minimise environmental impact and they have been precisely classified according to their nature: general practices, energy conservation practices, substitution of substances, practices to minimise waste water and air emissions, waste management practices and occupational health and safety practices.

- **Process Improvements (PIs) for the leather sector -** this section explains improvements that can be implemented in order to minimise the environmental impact during the different process stages. With regard to the tanneries, process improvements related to different stages have been included: beamhouse, tanyard operations, post-tanning operations, coating and other improvements. Furthermore, process improvements related to leather manufacturing have also been described, with the stages analysed being the following: design and product development, production (cutting, clicking, stitching, assembly, lasting), product finishing, full product packaging and end of life.

4 OBJECTIVE AND METHODOLOGY

This guide aims to foster the sustainability of the Bangladeshi leather sector. The guide compiles a wide variety of mechanisms, techniques, technologies and practices to minimise the environmental impacts related to the leather value chain.

The guide is divided into two main sections, best sustainable practices and process improvements. Within the best sustainable practices several actions have been described. These actions have been classified according to their nature: general practices, energy conservation practices, substitution of substances, practices to minimise waste water and air emissions, waste management practices and occupational health and safety practices.

The second part of the guide includes the description of numerous process improvements for each production stage, for both tanneries and leather manufacturing production processes.

The information included in this guide has been gathered from two different sources. Firstly, a bibliographic research and analysis was carried out and, among others, reference documents from entities such as the European Commission, the Asian Development Bank, the United Nations Industrial Development Organization and the World Bank were thoroughly examined.

In addition, it is worthwhile to highlight the valuable outputs collected through the involvement of the stakeholders. Several events have been organised in Dhaka, and experts belonging to different areas (SME owners, technical experts, environmental experts, policy makers, etc.) have made outstanding contributions to this guide.

Figure 1: Leather value chain

5 ENVIRONMENTAL HOTSPOTS AND CONSTRAINTS OF THE BANGLADESHI LEATHER SECTOR

At the beginning of ECOLEBAN project, an LCA study of the leather value chain was carried out. In this task the main environmental impacts related to the 3 leather subsectors (tanneries, footwear manufacturing and leather goods manufacturing) were assessed.

TANNERIES

According to the LCA study, the main environmental impacts of the production process in the tanneries are climate change, human toxicity, metal depletion and fossil depletion.

The figure below shows the contribution of the different inputs/outputs to each environmental impact:According to the results obtained, the process which has the highest environmental impacts is the production of the chemicals consumed in the tannery. More than 30 substances have been identified and quantified in the data inventory, but 9 of them are the most critical:

- Sodium sulphide
- Ammonium sulphate
- Formic acid
- Sodium formate
- Fungicide/biocide
- Phenolic syntan
- Phenol sulphonic acid condensate
- Alcohol ethoxylate
- Chromium sulphate

It must be highlighted that these chemicals/materials are not necessarily the most dangerous ones for the environment. The relevance of their contribution to the environmental impacts is also directly related to the amount consumed. In this sense, in order to improve the environmental performance of the footwear industry two different strategies could be implemented: (i) substitution of some chemicals/materials and (ii) minimisation of the consumption of the chemicals/materials.

Furthermore, the transportation of these chemicals from the countries where they are produced (China, Germany, Italy, France, Netherlands, etc.) to Bangladesh also generates some relevant environmental impacts, such as terrestrial acidification, marine ecotoxicity, photochemical oxidant formation and particulate matter formation.

The production of the electricity required in the tannery also contributes significantly to some environmental impacts: climate change, ozone depletion, human toxicity, fossil depletion, etc. The implementation of energy saving and energy efficiency measures can lead to significant environmental improvements.

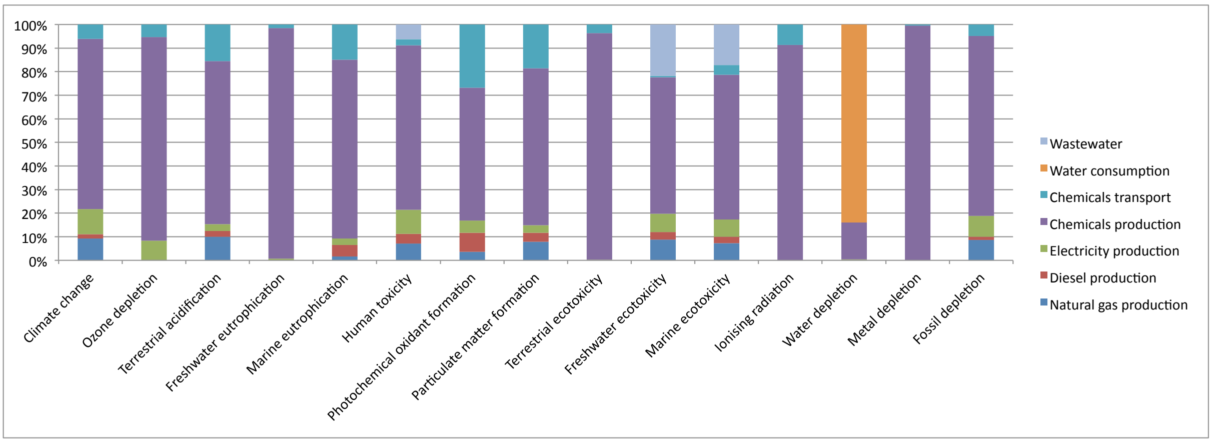


Figure 2: Contribution to the environmental impacts of tanneries

It is noteworthy to point out that the environmental impacts related to the production of the diesel consumed in the tannery are not significant because the diesel consumption calculated for the tannery standard is very low. Although the environmental impacts related to natural gas are important (climate change, terrestrial acidification, freshwater ecotoxicity, fossil depletion, etc.), it cannot be concluded that diesel is more environmentally friendly than natural gas, because the amount of natural gas consumed is much higher than the amount of diesel consumed.

FOOTWEAR MANUFACTURING

According to the LCA study, the main environmental impacts related to footwear manufacturing process are climate change, human toxicity, metal depletion and fossil depletion.
The figure below shows the contribution of the different inputs/outputs to each environmental impact:

According to the results obtained, the process which has the highest environmental impact is the production of the leather required for footwear manufacturing. In fact, the production of this leather represents around 51.9% of the environmental impacts.

In addition, the production of the chemicals and materials used during the production process of the footwear generates important environmental impacts, 32.9% on average. Several chemicals and materials have been identified and quantified in the data inventory, but those which contribute the most to the environmental impacts are the following:

- Polyurethane
- Rubber
- Adhesive
- Ethyl vinyl acetate
- Wax
- Cotton
- Stainless steel

It must be highlighted that these chemicals/materials are not necessarily the most dangerous ones for the environment. The relevance of their contribution to the environmental impacts is also directly related to the amount consumed. In this sense, in order to improve the environmental performance of the footwear industry, two different strategies could be implemented: (i) substitution of some chemicals/materials and (ii) minimisation of the consumption of the chemicals/materials.

The production of the electricity required in the footwear manufacturing process also contributes significantly to some environmental impacts: climate change, human toxicity, fossil depletion, etc. The implementation of energy saving and energy efficiency measures can lead to significant environmental improvements.

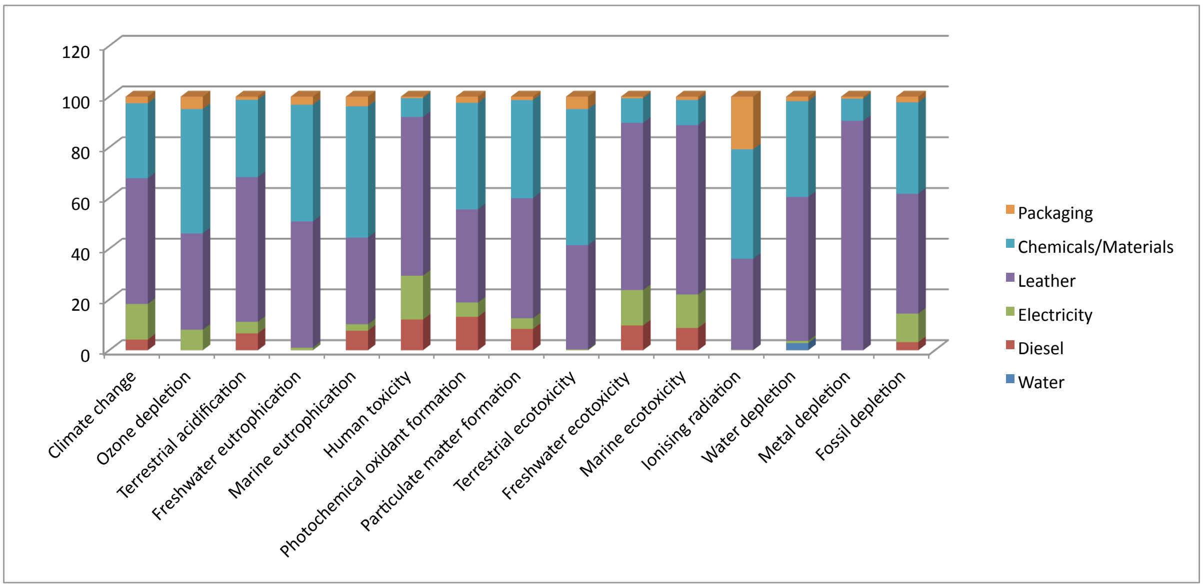


Figure 3: Contribution to the environmental impacts of footwear manufacturing

LEATHER GOODS MANUFACTURING

According to the LCA study, the main environmental impacts related to the leather goods manufacturing process are climate change, human toxicity, metal depletion and fossil depletion.

The figure below shows the contribution of the different inputs/outputs to each environmental impact.

According to the results obtained, the process which has the highest environmental impact is the production of the leather required for leather goods manufacturing. In fact, the production of this leather represents around 67% of the environmental impacts.

In addition, the production of the chemicals and materials used during the production process of the footwear generates important environmental impacts, almost 27% on average. Several chemicals and materials have been identified and quantified in the data inventory, but the ones which contribute the most to the environmental impacts are the following:

- Polyurethane
- Cotton
- Metals (aluminium, cobalt, copper, etc.)
- Adhesive
- Latex

It must be highlighted that these chemicals/materials are not necessarily the most dangerous ones for the environment. The relevance of their contribution to the environmental impacts is also directly related to the amount consumed. In this sense, in order to improve the environmental performance of the leather goods industry two different strategies could be implemented: (i) substitution of some chemicals/materials and (ii) minimisation of the consumption of the chemicals/materials.

The production of the electricity required in the leather goods manufacturing process also contributes significantly to some environmental impacts: climate change, human toxicity, fossil depletion, etc. The implementation of energy saving and energy efficiency measures can lead to significant environmental improvements.

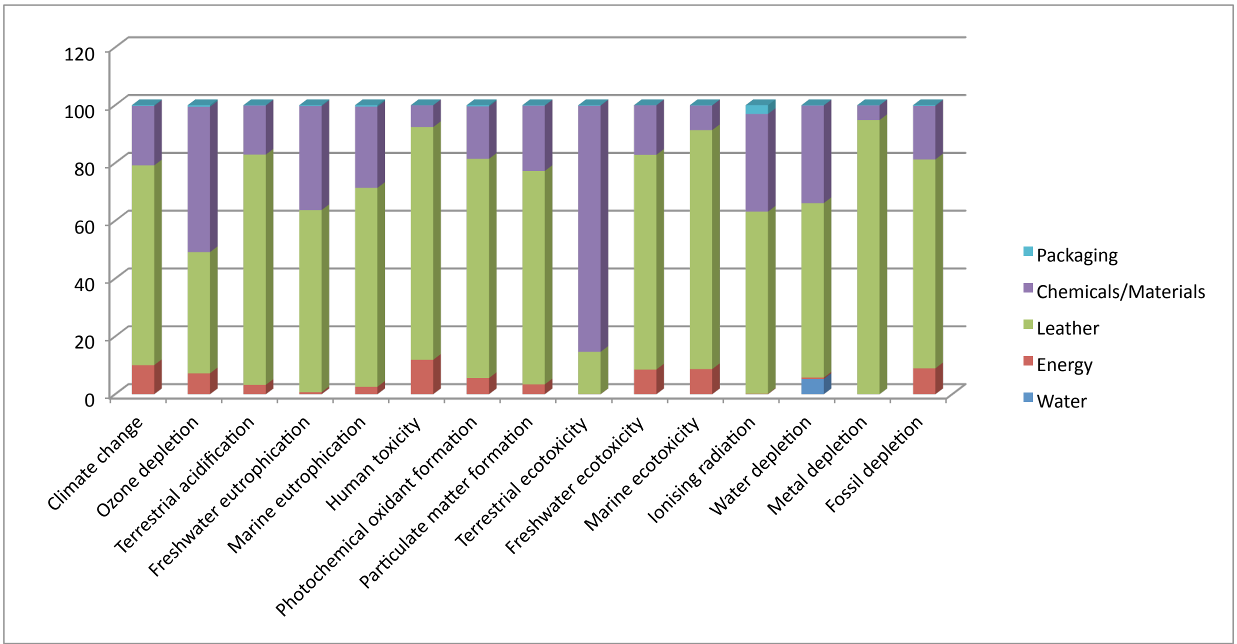


Figure 4: Contribution to the environmental impacts of leather goods manufacturing

6 BEST SUSTAINABLE PRACTICES

BSP 1 – GENERAL PRACTICES

BSP 1.1 – ENVIRONMENTAL MANAGEMENT SYSTEMS

An environmental management system (EMS) is a technique allowing operators of installations to address environmental issues in a systematic and demonstrable way. EMSs are most effective and efficient where they form an inherent part of the overall management and operation of an installation.

An EMS focuses the attention of the operator on the environmental performance of the installation; in particular through the application of clear operating procedures for both normal and other than normal operating conditions, and by setting out the associated lines of responsibility.

The cycle is an iterative dynamic model, where the completion of one cycle flows into the beginning of the next *(see figure below)*.

An EMS can take the form of a standardised or non-standardised ('customised') system. Implementation and adherence to an internationally accepted standardised system, such as EN ISO 14001:2004, can give higher credibility to the EMS especially when subjected to a properly performed external verification.

Figure 5: Continuous improvement in an EMS model

An EMS can contain the following components:

- Commitment of management, including senior management;
- Definition of an environmental policy that includes the continuous improvement of the installation by the management;
- Planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;
- Implementation and operation of procedures, paying particular attention to:
    - Structure and responsibility
    - Training, awareness and competence
    - Communication
    - Employee involvement
    - Documentation
    - Efficient process control
    - Maintenance programmes
    - Emergency preparedness and response
    - Safeguarding compliance with environmental legislation;
- Checking performance and taking corrective action, paying particular attention to:
- Monitoring and measurement
- Corrective and preventive action
- Maintenance of records
- Independent (where practicable) internal and external auditing in order to determine whether or not the ems conforms to planned arrangements and has been properly implemented and maintained.
- Review of the ems and its continuing suitability, adequacy and effectiveness by senior management;

- Preparation of a regular environmental statement;
- Validation by a certification body or external ems verifier;
- Following the development of cleaner technologies;
- Consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;
- Application of sectoral benchmarking on a regular basis.

BSP 1.2 – GOOD HOUSEKEEPING

In order to minimise the environmental impact of the production process, the following good housekeeping techniques should be applied:

- Careful selection and control of substances and raw materials (e.g. quality of hides, quality of chemicals);
- Input–output analysis with a chemical inventory, including quantities and toxicological properties;
- Minimisation of the use of chemicals to the minimum level required by the quality specifications of the final product;
- Careful handling and storage of raw materials and finished products in order to reduce spills, accidents and water wastage;
- Segregation of waste streams, where practicable, in order to allow for the recycling of certain waste streams;
- Monitoring of critical process parameters to ensure stability of the production process;
- Regular maintenance of the systems for the treatment of effluents;
- Review of options for the reuse of process/washing water;
- Review of waste disposal options.

BSP 1.3 - NOISE AND VIBRATION CONTROL

Good practices to control the emission of noise and vibration may use one or more of the practices listed below.

- The prevention of noise generation at source. Preventative maintenance and replacement of old equipment can considerably reduce the noise levels generated
- Change of operating speeds so as to avoid creating resonances. Avoiding operation of several machines of the same type at the same speed.
- Placing as much distance as possible between the noise source and those likely to be affected by it.
- Use of resilient machine mountings and drives to prevent the transmission of vibration.
- Using a building designed to contain the noise or a noise barrier.
- Silencing of exhaust outlets.

BSP 1.4 – MONITORING

Monitoring of the environmental outputs and emissions from an industrial activity is essential to their effective control.

Water – Standardised analysis and measurement methods exist for waste water effluent parameters such as COD, BOD, SS, TKN, ammonia, total chromium, sulphides, chloride, AOX, conductivity, pH and temperature that are set in the permit for tanneries or determined by the requirements of the waste water treatment plant they discharge to.

Particulate matter emissions do not require frequent precise monitoring once the efficacy of the equipment has been proved. Indicative or secondary monitoring can be used to check for correct operation. For example, the functioning of filtration equipment can be monitored by measuring the pressure drop across the filter.

Where emissions of hydrogen sulphide, ammonia or volatile organic compounds are sufficient to need abatement equipment, correct operation of that equipment must be checked by indicative monitoring. Alternatively secondary indicators such as the pH or redox potential of the liquid at the outlet from a wet scrubber can be used for daily monitoring.

The keeping of an organic solvent inventory is necessary to establish the total solvent emissions per m2 of leather produced.

At sites where nuisance is likely to be caused, monitoring of hydrogen sulphide, ammonia and other odorous substances at the downwind boundary of the site may be required. Since H2S and NH3 are detectable by humans in concentrations below the operational limits of portable measuring equipment, olfactory monitoring may be the only technique available. It is usual to deploy staff who does not work in the production areas for olfactory monitoring.

For other gaseous emissions, specific monitoring might be required; for example, if energy is generated on-site by combustion plants, or waste treatment plants are installed.

Waste fractions arising from the processes in the tannery need to be recorded according to type, amount, hazard and recycling or disposal route.

A chemical inventory is essential as part of good housekeeping techniques, and is essential in good environmental management of emissions and in accident preparedness programmes. *(see BSP 1.1 – ENVIRONMENTAL MANAGEMENT SYSTEMS).*

Energy – The consumption of water, electricity, heat (steam and heating), and compressed air, should be recorded, as part of a programme to manage these resources. A total of all the energy use at the installation should be calculated.

Noise – Where there are residences or other noise-sensitive locations near to the tannery, sound levels should be measured outside the tannery buildings on appropriate parts of the site. The measurement should include narrow band frequency analysis. When new equipment is installed, new measurements should be taken to detect any increase in the sound emissions or a change in their character.

The following table shows some recommendation regarding monitoring emissions and other relevant process parameters:

PARAMETER	FREQUENCY	APPLICABILITY
Measurement of water consumption in the two process stages: up to tanning and post-tanning, and recording of production in the same period.	At least monthly.	Applicable to plants carrying out wet processing.
Recording of the quantities of process chemicals used in each process step and recording of production in the same period.	At least yearly.	Generally applicable.
Monitoring of the sulphide concentration and total chromium concentration in the final effluent after treatment for direct discharge to receiving water, by using flow proportional 24-hour composite samples. Monitoring of the sulphide concentration and total chromium concentration after chromium precipitation for indirect discharge, by using flow proportional 24-hour composite samples.	On a weekly or monthly basis.	The monitoring concentration is applicable to on-site or off-site plants which undertake chromium precipitation. Where economically viable, the monitoring of sulphide concentration is applicable to plants carrying out some part of effluent treatment on-site or off-site for treating waste waters from tanneries.
Monitoring of chemical oxygen demand (COD), biochemical oxygen demand (BOD) and ammoniacal nitrogen after on-site or off-site effluent treatment for direct discharges to receiving water, by using flow-proportional 24-hour composite samples. Monitoring of total suspended solids after on–site or off-site effluent treatment for direct discharges to receiving water.	On a weekly or monthly basis. More frequent measurements in case process changes are needed.	Applicable to plants carrying out some part of effluent treatment on-site or off-site for treating waste waters from tanneries.
Monitoring of halogenated organic compounds after on-site or off-site effluent treatment for direct discharges to receiving water.	On a regular basis.	Applicable to plants where halogenated organic compounds are used in the production process and are susceptible to being released into receiving water.
Measurement of pH or redox potential at the liquid outlet of wet scrubbers.	Continuously.	Applicable to plants using wet scrubbing to abate hydrogen sulphide or ammonia emissions to the air.
The keeping of a solvent inventory on an annual basis, and recording of production in the same period.	On an annual basis.	Applicable to plants carrying out finishing using solvents and using water-borne coatings or similar materials to limit the solvent input.
Monitoring of volatile organic compounds emissions at the outlet of abatement equipment, and recording of production.	Continuously or periodically.	Applicable to plants carrying out finishing using solvents and employing abatement.
Indicative monitoring of pressure drop across bag filters.	On a regular basis.	Applicable to plants using bag filters to abate particulate matter emissions, where there is a direct discharge to the atmosphere.
Testing of the capture efficiency of wet scrubbing systems.	Annually.	Applicable to plants using wet scrubbing to abate particulate matter emissions, where there is a direct discharge to the atmosphere.
Recording of the quantities of process residues sent for recovery, reuse, recycling and disposal.	On a regular basis.	Generally applicable.
Recording of all forms of energy use and of production in the same period.	On a regular basis.	Generally applicable.

Table 1: Recommendations for monitoring emissions and other relevant process parameters

BSP 1.5 – DECOMMISSIONING

When decommissioning a plant in general, all provisions and measures have to be taken into account to prevent environmental impact during and after the shutdown process. The aim is to prevent impact on the environment in general and in particular on the immediate surroundings, by remediation techniques, to leave the area in such a way that it can be reused (depending on the enforcement bodies' decisions on land-use planning). This includes activities from the shutdown of a plant itself, the removal of buildings, equipment, residues, etc. from the site, and contamination of surface waters, groundwater, air or soil.

Records must be kept during the operation of the tannery of the location on the site at which each process step is undertaken. Drainage routes and waste storage locations must be included.

These records should be preserved systematically to allow the efficient planning of decommissioning. Additional records should be made each time activities or equipment are relocated, or when changes are made to process chemistry *(see BSP 1.1 – ENVIRONMENTAL MANAGEMENT SYSTEMS)*.

The legal framework for the decommissioning of installations varies greatly between Member States, and any provisions and duties laid down in a permit will depend strongly on the local environment and on the legislation to be applied, in particular with respect to liability. Thus, in this document only general guidelines can be given on the possible impacts and the provisions to prevent impacts at three stages:

- what conditions in the permit for processing at a site can be set to prevent negative long-term effects on the environment during operation and after decommissioning;
- what has to be taken into account consequently during operation;
- what prerequisites are to be considered for the final shutdown and what contamination might be caused.

The large quantities of raw materials and waste handled by tanneries mean that the prevention of soil and groundwater contamination is a high priority with regards to spillage, storage, processing, and final decommissioning.

Furthermore, for floors in general, not only in storage rooms, it is common practice that surfaces are used that facilitate cleaning and removal of spillage and have limited permeability.

Retention tanks for process liquors, chemicals, and waste water effluents; basins and drainage systems for the collection of effluents; and storage containers for waste are mostly impermeable to prevent leakage to the soil and surface water.

BSP 2 – ENERGY CONSERVATION

BSP 2.1 – ENERGY MANAGEMENT PROGRAMMES

Energy management programmes should include the following elements:

- Identification, and regular measurement and reporting of principal energy flows within a facility at unit process level;
- Preparation of mass and energy balance;
- Definition and regular review of energy performance targets, which are adjusted to account for changes in major influencing factors on energy use;
- Regular comparison and monitoring of energy flows with performance targets to identify where action should be taken to reduce energy use;
- Regular review of targets, which may include comparison with benchmark data, to confirm that targets are set at appropriate levels.

BSP 2.2 – ENERGY EFFICIENCY

The following are some energy conservation measures for the leather sector:

Motor Efficiency: About 80% of the electrical energy is consumed by the motors used in manufacturing equipment and utilities. These motors are operated for 6,000 to 7,000 hours a year. Currently, high-efficiency motors (HEMs) are not installed in factories. HEMs have 10-20% greater efficiency as compared to motors used in Bangladesh. The payback for replacing the existing motors with HEMs is only 12-18 months.

Boiler Efficiency: In leather facilities boilers are used for steam generation and hot water. The current stock of boilers in Bangladesh is old. There is no measurement of air to the boiler, which plays a crucial role in the efficiency of the boiler. Generally, air dampers are found to be set at one position and not adjusted even when load fluctuates. By adjusting air dampers based on the continuous measurement of oxygen in the flue gases, boiler efficiency can be improved by 6-8%. In several of the facilities audited, the boiler insulation is not sufficient. In some facilities it was found that single-pass boilers are in use. Replacing these boilers with three-pass boilers will increase the boiler efficiency by 15-20%.

Variable Frequency Drives: Adding a variable frequency drive (VFD) to a motor-driven system can offer potential energy savings when system loads vary over time. For example, in the stitching of garments VFDs are used to reduce the speed of sewing machines during unload conditions. In general, controlling the speed of a pump, rather than controlling flow through the use of throttling valves or nozzles, can yield energy savings of 50% for a reduction in speed of 20%. VFDs can be installed on washer pump motors, fan motors to control flow, in humidification plants, and in air compressors.

Lighting: The ready-made garments and footwear industries require adequate lighting during stitching, sewing and finishing processes. Only a few factories have progressed towards energy efficient lighting systems by replacing T-8 tubes with T-5 tubes. Furthermore, in Bangladesh, high-intensity discharge lamps with metal halide or high-pressure sodium are not common; these can yield 50-60% energy savings over fluorescent alternatives. Replacing magnetic ballasts with electronic-ballast fluorescent lighting can save 25%. Industry should move toward Light Emitting Diode (LED) lighting rather than T-5 or T8, which saves roughly 25% and 35%, respectively, has a longer life and is more environmentally friendly.

Replace Diesel/Furnace Oil Water Boilers with Solar Water Boilers: The long-term average solar irradiation data indicates that the period of high-intensity (i.e. more than 200 W/m2) sun-hours in Bangladesh varies from 3 to 11 hours daily and that the global radiation varies from 3.8 to 6.4 kWh/m2/day. These data indicate that there are good prospects for solar, thermal and photovoltaic applications in Bangladesh such as solar heating. Furthermore, as the cost of solar generators has been decreasing while the cost of diesel has been increasing, they are now in a position to replace diesel generators.

BSP 2.3 – REDUCING ELECTRICAL CONSUMPTION BY INTRODUCING THE POWER FACTOR

AC power is transmitted with the least losses if the current is undistorted and exactly synchronised with the voltage. Light bulbs and resistance heaters draw current that is exactly synchronised and proportional to voltage, but most other loads tend to draw current with a time lag (i.e. phase shift) or to distort it (i.e. introduce harmonics). It takes more current to deliver a fixed amount of power when the current is phase shifted or distorted.

The ratio of the actual power transmitted ('real power') to the apparent power that could have been transmitted if the same current were in phase and undistorted is known as the power factor. It is always less than or equal to 1. The reduction of electrical consumption by improving the power factor and performance improvement of electrical equipment (especially electrical motors) has been a great success in Bangladesh's tannery sector. The main benefits of implementing the power factor are to improve electrical motor efficiency, increase the internal electrical system's capacity, reduce voltage drop at the point of use and reduce energy (apparent) consumption as well as the monthly electricity bill.

Low power factor requires an increase in the electric utility's transmission and distribution capacity in order to handle the reactive power component caused by inductive loads. Mostly induction motors are used in the tannery sector. Electricity is the main source to drive these motors. Induction motors are inductive load which have low lagging PF. These motors work at a PF which is extremely small on light load (0.2 to 0.3) and rises to 0.8 to 0.9 at full load. The power factor should maintain within the range 0.95 lag to 0.95 lead. Otherwise, the power factor charge will be applied. The average PF in the tannery sector is 0.4 lag to 0.6 lag, so PF improvement is necessary. Let's say the average power factor in a tannery is = 0.7 lagging. It can be maintained up to unity (1.0). 42% (1/0.7 = 1.42) of the apparent energy can be saved by improving the power factor from 0.7 lagging to unity (1.0).

BSP 2.4 – SOLAR COLLECTOR INSTALLED IN TANNERY

Bangladesh is fortunate to have a geographical location where sunlight can be available for more than 10 hours during the daytime. There has been a successful initiative in installing solar collectors in two leather processing units in Hazaribagh

Figure 6: Solar collectors installed in a tannery under UNIDO project in Bangladesh. Source: UNIDO

Tannery Area. The most effective and cheapest method to use the sun's energy is its conversion to thermal energy. The solar thermal energy can be used by direct heating of the process fluid (water) or heating of special fluids and the heat is then transmitted to the process water by the heat exchanger.

The installations containing the storage vessel are more used than the direct use of the heated fluid. The solar thermal energy production and the efficiency of the transformation of the solar insolation energy to thermal energy depend on many factors, such as location, type of solar collectors and their installation and, most importantly, on the desired temperature of the heated fluid. The maximal efficiency of solar thermal collectors is 50–80%, and the efficiency of the whole installation is 30–50%. In practice, even in hot climate zones it is not possible to rely on solar heating alone and a fuel-fired boiler is necessary. Electric energy needed for the fluid/water circulation and transfer pumps should not be overlooked, either. In any case, it is important to conduct a proper study to design the optimum installation with the desired temperature of the hot water, work out the efficiency and ultimately, the type and cost of the solar collector and of the entire installation.

The second important thermal energy consumption is leather drying. Solar thermal energy can be used for direct heating of the air; alternatively, special fluids can be used so that the heat is transferred to the air by a heat exchanger, similarly as for hot water preparation. Practically everything that was mentioned about the use of solar thermal energy for water heating also applies to air heating, except for the limitation of storing the hot air. This means that if hot air is used directly for drying, the working hours of the air heating should be synchronised with the working hours of the leather drying.

BSP 3 – SUBSTITUTION OF SUBSTANCES

BSP 3.1 - SUBSTITUTION OF OCTYLPHENOL AND NONYLPHENOL ETHOXYLATES

This practice strives to use linear alcohol ethoxylates, polyglycol ether instead of alkylphenol ethoxylates in the aqueous degreasing of sheepskins.

Surfactants are used in many different processes throughout the tannery, e.g. soaking, liming, degreasing of sheepskins, tanning and dyeing. Nonylphenol ethoxylate (NPE) surfactants were used in the leather industry in the past. NPEs can be degraded to smaller chain NPEs and nonylphenol, both of which are toxic. The European Union carried out an extensive risk assessment of nonylphenol which concluded that nonylphenol displays an endocrine-disrupting activity.

The use of NPE in leather processing is now restricted under the REACH regulation. Its use is banned except for (a) activities with no release to waste water or (b) 'systems with special treatment where the process water is pretreated to remove the organic fraction completely prior to biological waste water treatment (degreasing of sheepskins)' specified in point 46 of Annex XVII of the regulation. In sheepskin processing, a closed loop cycle is adopted in order to avoid discharges of octylphenol and nonylphenol ethoxylates.

Good housekeeping techniques help to achieve general emissions reduction *(for water management see BSP 4.1 - PROCESS WATER MANAGEMENT)*.

The main alternatives in the degreasing of sheepskins are linear alcohol ethoxylates with different chain lengths and ethoxylation degrees. These compounds show a much lower toxicity than NPE and can be degraded to non-toxic compounds.

The efficacy of C10 linear alcohol ethoxylate as a degreasing agent is comparable to that of NPE. In this application a nanophase with very low surface energy is formed that is converted into a macroemulsion.

A process for recovery of the surfactant and fat by solvent distillation using heptane and ethanol has been demonstrated on a pilot scale. The best recovery rate found was 75%.

Possible differences in their effectiveness have to be taken into account in case of the need for a change in the quantity used. All of the aliphatic ethoxylated alcohols have distinct properties, so the process design differs depending on the material chosen.

BSP 3.2 - SUBSTITUTION OF HALOGENATED ORGANIC COMPOUNDS IN DEGREASING

There are possibilities for replacing halogenated organic compounds, either by using non-halogenated solvents or by changing over to an aqueous degreasing system.

Linear alkyl polyglycol ethers, carboxylates, alkyl ether sulphates and alkyl sulphate can be used instead of halogenated solvents. Solvent degreasing will result in some air emissions of solvents, even though solvents are recovered.

Storage, handling and transport require special precautions in order to prevent contamination of the soil through spillage and to curtail fugitive emissions. Prevention measures such as closed systems, solvent recycling, emission abatement techniques and soil protection can considerably reduce the emissions.

When halogenated solvents have to be used, prevention and abatement measures have to be adapted specifically. Fugitive emissions from solvent degreasing systems can be minimised by the use of closed cycle machines.

BSP 3.3 - SUBSTITUTION OF HALOGENATED ORGANIC COMPOUNDS IN FATLIQUORS

This practice refers to the use of fatliquors which do not contain halogenated compounds.
Fatliquors are available that do not require stabilisation by organic solvents (and therefore do not contribute to the AOX) and perform with improved exhaustion, for example, fish oils.

Short-chain and middle-chain chlorinated alkanes in fatliquors can now be replaced, e.g. by fatliquoring polymers based on methacrylates, or by silicone oils or modified silicone oils.

For special applications, no substitute has yet been found for long-chain chlorinated alkanes.

BSP 3.4 - SUBSTITUTION OR OPTIMISATION OF HALOGENATED ORGANIC COMPOUNDS IN WATER-, SOIL- AND OIL-REPELLENT AGENTS

Use of water-repellent agents, oil-repellent agents, and soil-repellent agents, which do not contain halogenated organic compounds: when a complete substitution is not possible, optimised fluorocarbon resins in combined finishes for water-, soil- and oil-repellent leather are used to reduce the release of halogenated organic compounds.

Like fatliquors, these agents can also contain organic solvents and organic halogenated compounds.

For leather requiring only a water-repellent finish, halogen-free water-repellent agents with a different chemical basis are used depending on the specified finish requirements, e.g. paraffin formulations, polysiloxanes, modified melamine resins or polyurethanes. For combined water-, soil- and oil-repellent finishing of leather, in most cases fluorocarbon resins are still used.

Fluorocarbon resins are used because of their very good water-, soil- and oil-repellency and high permanence of the repellency effect. A typical aqueous formulation contains 20–30% active polymer compound with 20–50% fluorine in the polymer.

In the past, unintended by-products from the production of these fluorocarbon resins, for example perfluorooctane sulphonates (PFOS) and perfluorooctanoic acid (PFOA), caused concern in view of health and environment considerations. These fluorocarbon resins are currently replaceable by optimised fluorocarbon resins based on raw materials with a chain length of four (C4) or six (C6) rather than a chain length of eight (C8). The shorter-chain fluorocarbon resins are more favourably assessed toxicologically, although they are as stable in the environment. Consequently, preventative measures are also applicable for optimised fluorocarbon resins, in order that their release into the environment be minimised by the use of controlled application processes with high exhaustion, as well as the retention and controlled disposal of segregated liquor residues, if no recycling is possible.

The use of halogen-free agents can result in a decrease of the COD and the elimination of halogenated compounds from the effluent. Optimised fluorocarbon resins reduce the emissions of PFOS and PFOA and their precursor compounds into the environment.

BSP 3.5 - SUBSTITUTION OF HALOGENATED ORGANIC COMPOUNDS IN FLAME RETARDANTS

This practice is related to the use of flame retardants which do not contain halogenated organic compounds.

There are alternatives to brominated flame retardants for the leather industry. Firm leather with a dense fibre interweaving is more flame-resistant than other leather types. Therefore, flame resistance is possible by applying appropriate syntans and the addition of melamine resins in the retanning process, as well as by selecting suitable fatliquors. Furthermore, the application of ammonium bromide (for example) leads to a flame-retardant effect that is sufficient for some applications.

Inorganic phosphorus compounds (such as ammonium polyphosphate) could be considered an alternative to brominated flame retardants.
Silicon polymer products used in finishing can confer some fire resistance, in that they burn to leave a residue of silica (SiO2), which protects the leather beneath.

BSP 3.6 - ELIMINATING PESTICIDES FROM THE RAW MATERIAL (HIDES/SKINS)

This sustainable practice is focused on the selection of materials free from persistent pesticides which are resistant to effluent treatments.

Many pesticides are classified as POPs (Persistent Organic Pollutants). Pesticides are normally used neither in preservation nor in the course of leather manufacture; their presence is due to the application of pesticides to protect animals from ectoparasites. Many pesticides are harmful and to make it worse, some of them, like synthetic pyrethroids and organophosphates, are not destroyed throughout leather processing or even during effluent treatment.

The use of HCH, DDT and naphthalene is prohibited in Europe, but they might end up in the waste waters of tanneries processing raw material from countries where legislation and/or enforcement are not strict.

To prevent the arrival of materials contaminated by banned pesticides and biocides in the tannery, it is possible to use supply chain contracts specifying that only hides or skins that are free from these materials shall be supplied.

BSP 3.7 – USE OF APPROVED BIOCIDES

Biocides may be used in the curing, soaking, pickling, tanning and post-tanning processes. Only approved biocides, or biocides still allowed, should be used and special attention needs to be paid to the conditions for product use. It is anticipated that only a limited number of biocides will be supported for the leather industry.

Biocides are applied to raw hides and skins (bactericides) and in pickling/tanning (fungicides) to stop the leather being damaged during transport and storage. Over the years there have been a number of changes in the fungicides used to treat leather against fungal attack. If we go back far enough, phenyl mercury compounds like phenylmercuric acetate (PMA) were in common use. Then we saw the emergence of chlorinated phenols like pentachlorophenol (PCP). By the early 1980s the use of these compounds had fallen out of favour or become restricted, principally due to their high toxicity to humans, their environmental problems and/or their aggressiveness in handling. The fungicide 2-(thiocyanomethylthio) benzothiazole (TCMTB) became the new standard starting in the 1970s and remains in use today. However, with ever increasing demands for safer and environmentally sound fungicides, microbicide manufacturers continue to search for new products that can meet these demands.

The following specific biocides are commonly restricted:

- Chlorophenols (their salts and esters);
- Polychlorinated biphenyls (PCB);
- Organotin compounds, including TBT, TPhT, DBT and DOT;
- Dimethyl fumarate (DMFu);
- Nanosilver;
- Triclosan.

So now only a few fungicides dominate the leather industry usage.

The big 4 fungicides are commonly known by their abbreviations, for example, PCMC (para-chloro-meta cresol), OIT (2-n-octylisothiazolin-3-one), OPP (ortho-phenylphenol), TCMTB (2-thiocyanomethylthio) benzothiazole).

The ecolabel, 'Der blaue Engel' (the Blue Angel), gives recommendations for allowable limits in leather of the active fungicide components: PCMC < 600 mg/kg, OIT < 250 mg/kg, OPP < 1000 mg/kg and TCMTB < 500 mg/kg.

BSP 3.8 - SUBSTITUTION OF COMPLEXING AGENTS

This practice is regarding the use of complexing agents that do not contain EDTA or NTA. Complexing agents such as EDTA (ethylenediaminetetraacetatic acid) and NTA (nitrilotriacetic acid) are used as sequestering agents. Apart from impeding the waste water treatment, complexing agents have an adverse impact on the environment.

EDTA poses a particular hazard because of its long life in the environment. NTA is more easily biodegradable but its use is undesirable. Polyphosphate-based and phosphonate-based products can be used instead of EDTA and NTA in the dyeing or the pretanning to wet white.

The substitution of these substances is environmentally beneficial. EDTA is poorly biodegradable and may increase the discharge of chromium in the waste water by re-mobilising it from the sludge during effluent treatment. *See also BSP 4.1 - PROCESS WATER MANAGEMENT*.

BSP 3.9 – USE OF APPROVED DYES

A dye is a coloured substance that has an affinity to the substrate to which it is being applied. It is an ionising and aromatic organic compound. The dye is generally applied in an aqueous solution, and may require a mordant to improve the fastness of the dye on the fibre.

The types of dyestuff that are used by tanneries generally vary depending on the product range needed along with the dictates of the fashion world. It is a fact that each tannery uses between 50-100 or more different types of dyestuffs.

The leather industry primarily uses anionic dyestuffs, which can be divided in the following families:

- Acid dyes
- Mordant dyes
- Direct dyes
- Basic dyes,
- Pre-metallised dyes
- Solubilised sulphur dyes
- Reactive dyes, part of the anionic group of dyes, but their use is limited to a certain extent.

The majority of the dyes used by the leather industry are water-based acid dyes (which account for about 90% of the market), direct dyes, mordant dyes, pre-metallised dyes, and solubilised sulphur dyes. From the chemical point of view, the dyestuffs are predominantly azo dyes, or anthraquinone dyes.

BSP 3.10 – FORBIDDEN SUBSTANCES

The next chemical groups may not be used during manufacturing of the raw material or the manufacturing of the product.

- Alkylphenol (AP) and alkylphenol ethoxylates (APEOs): including all isomers
- Chlorobenzenes and chlorotoluenes
- Chlorinated paraffins
- Chlorophenols
- Dyes – Azo dyes (forming restricted amines)
- Dyes - Navy Blue Colourant
- Dyes - CMR dyes
- Flame retardants
- Glycols
- Halogenated solvents
- Organotin compounds
- Polycyclic aromatic hydrocarbons (PAHs)
- Perfluorinated and polyfluorinated chemicals (PFCs)
- Phthalates – including all other esters of ortho-phthalic acid
- Total Heavy Metals
- Volatile Organic Compounds (VOC)

BSP 4 – WASTE WATER

BSP 4.1 – PROCESS WATER MANAGEMENT

Good process water management is achieved by determining the optimum quantity required for each process step and introducing the correct quantity using simple measuring equipment. Batch washing involves washing of hides and skins during processing by introducing the required quantity of clean water into the processing vessel and using the action of the vessel to achieve the required agitation, as opposed to using the agitation provided by the inflow and outflow of large quantities of water.

The first step to efficient process water management involves optimisation of water consumption and lowering the consumption of chemicals used in the process and in the waste water treatment. That will reduce both the necessary size of the waste water treatment plant and the energy consumption. Although a reduction of water consumption does not reduce the load of many pollutants, physico-chemical treatment of concentrated effluents is more efficient.

Consequently, cost reductions are achieved in many cases, but the biological treatment stages may become more difficult.

Process efficiency is achieved by optimisation of the mechanical movement, good distribution of chemicals and control of the chemical dosage, pH, and temperature, which are essential parameters for both quality and effective use of the plant. The installation of the equipment and the necessary access are also key issues to consider for the delivery of water and complete rapid removal of floats.

The efficiency of water use can be enhanced by: increased volume control of processing water, 'batch' versus 'running water' washes, use of short floats and an effective preventive and corrective maintenance programme. These measures are described below.

a. Increased volume control of processing water

It is found that in tanneries with poor water management, only 50% of the water consumed is actually used in the process; the other half is lost due to extensive running water losses, overflowing vessels, leakage, continuously running pipes and too frequent cleaning of floors and drums. Measures to be taken against inefficient use of water involve a serious worker-training programme, a clearly communicated code of practice for operators including information about cleaning cycles, and the installation of basic technical equipment such as flow meters and relatively simple spring valves.

b. 'Batch' versus 'running water' washes

The consumption of water for rinsing processes varies considerably between tanneries. Running water washes are one of the major sources of water wastage. The control with regard to flow rate and time necessary is minimal. Batch washes often yield a savings of over 50% of the total water. As a further advantage, a great uniformity of the end product is attained.

c. Modifying existing equipment to use short floats

The short-float technique yields a reduction in water consumption and processing time, and savings in chemical input because of a higher effective concentration and increased mechanical action. By modifying the equipment to utilise short floats, 40–80% floats, instead of 100–250%, are achieved for certain process steps.

With a combination of batch washing and short floats, savings of up to 70% can be achieved, compared with a conventional process. Attention has to be paid, however, to the consequences for the equipment and the pelts. Short floats may increase wear on the drum bodies and the drive. Water also functions as a coolant during the process. The friction and mechanical strain on the goods are increased.

The use of drums is generally better than paddles or pits, which use about 300–1,000% floats. However, because not all the types of leather produced can be processed in drums, certain tanneries will not be able to take advantage of this option to reduce their water consumption, e.g. the processing of long-wool skins must be done in paddles.

d. Using modern equipment for short floats

The installation of modern tannery machines can reduce water consumption by 50% (compared with a conventional process) in addition to chemical savings. Depending on the cost of water, the high cost of the machines can often be justified by the water and chemical conservation and reduction of chemical input they make possible. Only minimal remodelling may be required to allow for recycling systems, as most units already achieve efficient drainage.

e. An effective preventive and corrective maintenance programme

Leaks in pipes and process vessels can account for considerable losses of water. Preventative maintenance programmes can prevent losses from occurring while corrective maintenance can minimise the loss.

Economising in the use of water does not in itself reduce the pollution load, but nevertheless it has a number of beneficial effects: saving energy as a consequence of saving hot water; improved uptake of chemicals and consequent savings of chemicals result from the use of shorter floats; the use of batch washing makes better control possible. Additionally and importantly, the lower effluent volume makes it possible to construct a waste water treatment plant with a smaller capacity in the physico-chemical stages, or to increase the efficacy of physico-chemical treatment in an existing treatment plant.

BSP 4.2 – INDUSTRIAL PROCESS WASTE WATER

- Reduction of water consumption, through recycling of process streams.
- Use of 'batch' instead of 'running water' washes.
- Segregation of waste water streams (e.g. soaking liquors, sulphide-rich lime liquors, and chrome-containing liquors) to improve treatment speed and efficiency. Segregation of water streams also helps to isolate particularly concentrated or toxic compounds, such that they can be removed separately and possibly recovered for reuse.
- Use of short (e.g. low-water content) floats in the tanning cycle (e.g. floats using from 20 to 40% water with respect to normal floats), which allow for water savings of up to 70% and facilitate chrome fixation (when combined with increased temperature at the end of the tanning operation).
- Chemical substitution for less toxic and more biodegradable chemicals.

BSP 4.3 – COD/BOD AND SUSPENDED SOLIDS

- Screen waste water to remove large solids.
- Use an enzymatic dehairing process and recover hair for resale, reducing COD by up to 40–50%).
- If a conventional lime dehairing process is used, filter waste water to recover hair before dissolution. This may reduce COD by 15–20% and total nitrogen by 25–30% in mixed tannery effluent.
- Recycle liming float which may reduce COD by 30–40%; nitrogen by up to 35%, sulphide use by up to 40%, and lime use by up to 50%.
- Use easily degraded ethoxylated fatty alcohols, instead of ethoxylated alkylphenols, as surfactants in degreasing.
- Use carbon dioxide (CO2) deliming (e.g. for light bovine hides of less than 3 mm thickness). For thicker hides, the process requires an increase in the float temperature (up to 35°C), and/or process duration, and/or the addition of small amounts of deliming auxiliaries.

BSP 4.4 – SALTS AND TOTAL DISSOLVED SOLIDS

- Use of natural drying of small skins at facilities in suitably warm, dry climates.
- Use of chilling for short-term preservation of freshly processed hides or skins, and/or use of antiseptics to increase storage time.
- Undertake trimming and, where possible, prefleshing before curing or other pretanning operations.
- Use of mechanical or manual removal of salt from hides and skins before soaking.
- Installation of salt-free pickling systems, and use of non-swelling polymeric sulphonic acids (this may affect leather characteristics).
- Use of ammonium-free deliming agents (e.g. weak acids or esters) or CO2 deliming instead of ammonium salts.
- Using short floats in tanning to reduce chemical loads.

- Chrome fixation during tanning is enhanced by the use of high-exhaustion tanning process techniques including short floats, increased temperature, increased tanning times, increased basification and decreases in the level of neutral salts.

- Direct recycling of the pickling float, where practical (if tanning is performed in the float, only partial recycling of the exhausted tanning bath is possible).

- Direct recycling of tanning floats.

- Recycling of supernatant from chrome recovery to enhance chrome savings.

- Use of liquid dyes and syntans.

BSP 4.5 – SULPHIDES

- Use an enzymatic dehairing process.

- For conventional lime dehairing processes, use sulphide and lime in a 20–50% overall solution.

- Maintain sulphide-containing waste water at an alkaline pH (> 10) level. The conventional treatment is lime and sulphide waste water oxidation (catalytic oxidation tanks or aeration tanks). Care should be taken to avoid an accidental pH value–dependent (pH < 7) release of hydrogen sulphide (H2S), arising from, for example, inappropriate mixing of alkaline and acid streams, and uncontrolled release from denitrification steps.

BSP 4.6 – NITROGEN COMPOUNDS

- Use ammonium-free deliming agents (e.g. weak acids or esters) if CO2 deliming is not implemented.

- Where ammonia discharge might adversely affect the receiving water, include denitrification in waste water treatment to convert ammonia nitrogen to nitrates, although careful control and management is needed to limit the potential risk of H2S formation.

BSP 4.7 – CHROMIUM AND OTHER TANNING AGENTS

- Consider using alternative tanning agents in place of, or in addition to, chromium, considering the toxicity and persistence of the alternative agents as well as the use and desired characteristics of the leather product.

- Avoid the use of chromium(VI), by limiting the type of chromium employed to chromium(III).

- Recycle chrome tanning floats. This may reduce chromium use up to 20% in a conventional tannery process, and up to 50% in wool-on sheepskins. Liquor containing excess chromium may be precipitated, acidified and then recycled.

- Reduce chromium concentration in the waste float by using high-exhaustion chromium salts and alkaline products and/or increasing the float temperature.

- Avoid the use of chromium because it can adsorb onto the surface of organic particles of varying sizes and may not precipitate out of solution. Care must be taken that these particles are not mixed with the tannery effluent and discharged, using polyelectrolytes.

- Avoid disposal of chrome tanning sludge through incineration, alkaline conditions and the presence of excess oxygen can lead to the conversion of Cr(III) into more toxic Cr(VI).

BSP 4.8 – POST-TANNING CHEMICALS

- Avoid the use of halogenated compounds (e.g. in fatliquors).
- Recover impregnating agents from effluents.
- Avoid the use of sequestering and wetting agents with low biodegradability compounds (e.g. ethylenediaminetetraacetatic acid).
- Avoid the use of dicarboxylic acids for the precipitation of chromium during pretreatment of effluent.

BSP 4.9 – BIOCIDES

- Avoid the use of banned chlorinated/ halogenated phenols, as well as banned, and less biodegradable, biocides containing arsenic, mercury, and chlorinated substances.
- Monitor use of biocide inputs by keeping an inventory of biocide inputs and outputs.
- Management measures for the handling of hazardous chemicals are provided in BSP 7 – OCCUPATIONAL HEALTH AND SAFETY.

BSP 4.10 – RAINWATER MANAGEMENT

The amount of rainwater which falls onto a tannery site will vary according to the weather pattern for the locality, but its management involves some more general considerations.

It is good practice for rainwater falling on the roofs of the buildings to be collected separately from the process effluent so as to reduce the volume of water requiring treatment. It may be useful to store it for use in process operations or cleaning.

A further reduction in the volume of water to be treated can be obtained if rainwater falling onto paved yard areas, which cannot become contaminated with materials from the process, is also diverted away from the process effluent stream. This rainwater may be less suitable for use as a water source. These yard areas can be defined as those protected from contamination or the inflow of contaminated water by permanent physical barriers.

Rainwater from paved yard areas in which spills of process liquids or chemicals are likely to occur is collected as a process effluent. It is good practice to design operations so that the yard area used is as small as possible, so as to minimise the amount of rainwater collected. Effluent treatment arrangements are designed to cope with rainwater from this source.

Where an appropriate system of environmental management is in place, a further reduction of the yard area permanently drained to the process effluent stream can be achieved. This involves the drainage of identified paved areas where spillages are 'possible but unusual'. Rainwater from these areas can be directed away from the process effluent stream in normal circumstances, but with equipment available to divert contaminated water into the process effluent stream in the event of an accident.

This sustainable practice can achieve a reduction of the volume of water to be dealt with as process effluent, a reduction of the risk of overwhelming effluent treatment equipment in periods of heavy rain, and control of the risk of spillages being washed into surface waters.

Every tanner should design the building with the provision of rainwater harvesting facilities.

	Raw trimming	Limed trimmings	Tanned trimmings
Uses as a by-product	-	Collagen production	Patchwork, small leather goods, etc.
Reuse after preparation	-	Production of technical gelatine, tallow or protein hydrolysate	Leather fibreboard production for non-finished trimmings Protein hydrolysate
Recycling as	Hide glue	Hide glue	
Other recovery	Generation of biogas by anaerobic digestion	Generation of biogas by anaerobic digestion	Generation of biogas by anaerobic digestion

Table 3: Options for dealing with raw, limed and tanned trimmings

Figure 7: Shaving machine. Source: UNIDO

BSP 5 – AIR EMISSIONS

BSP 5.1 – ORGANIC SOLVENTS

- Consider water-based formulations (containing low quantities of solvent) for spray dyeing.
- Implement organic solvent-saving finishing techniques such as roller coating or curtain coating machines where applicable (e.g. application of heavy finish layers), and otherwise use spraying units with economisers and high-volume low-pressure spray guns.
- Prohibit the use of internationally banned solvents.
- Control VOC emissions through the application of secondary control techniques, such as wet scrubbers (including the use of an oxidising agent to oxidise formaldehyde), activated carbon adsorption, biofilters (to remove odours), cryogenic treatment, and catalytic or thermal oxidation.
- Replacement of halogenated volatile organic compounds used in the process with substances that are not halogenated.
- Use of extraction ventilation and an abatement system to reduce the airborne emissions of volatile organic compounds from finishing.

BSP 5.2 – SULPHIDES

- Maintain a basic pH over 10 in facility equalising tanks and sulphide oxidation tanks.
- Prevent anaerobic conditions in sulphate-containing liquors and sludge.

Add manganese sulphate to treated effluent, as needed, to facilitate the oxidation of sulphides.

- Where H2S formation may occur, use adequate ventilation to capture the emissions, followed by treatment with wet scrubbers or biofilters (particularly for waste water treatment units).

BSP 5.3 – AMMONIA

- Ammonia emissions may be generated from some of the wet processing steps (e.g. deliming and dehairing, or during drying if it is used to aid dye penetration in the colouring process). Prevention and control of ammonia emissions may be achieved through use of adequate ventilation, followed by wet scrubbing with an acidic solution.

BSP 5.4 – DUST / PARTICULATE MATTER

In order to reduce the dust / particulate matter emissions, the following technique should be employed:

- Dust / total particulate may be generated from various operations (e.g. storage and handling of powdery chemicals, dry shaving, buffing, dust removal machines, milling drums and staking). Dust emissions should be controlled through the use of an extraction ventilation system, centralised system, employing cyclones, scrubbers, and/or bag filters, as needed.

- Ventilation is a method of control that strategically 'adds' and 'removes' air in the work environment. Ventilation can remove or dilute an air contaminant if designed properly. Local exhaust ventilation is very adaptable to almost all chemicals and operations. It removes the contaminant at the source so it cannot disperse into the work space and it generally uses lower exhaust rates than general ventilation (general ventilation usually exchanges air in the entire room).

- Local exhaust ventilation is an effective means of controlling workplace exposures but should be used when other methods (such as elimination or substitution) are not possible.

- The design of a ventilation system is very important and must match the particular process and chemical or contaminant in use. Expert guidance should be sought. It is a very effective control measure but only if it is designed and maintained properly. Because contaminants are exhausted to the outdoors, you should also check with your local environment ministry or municipality for any environmental air regulations or bylaws that may apply in your area.

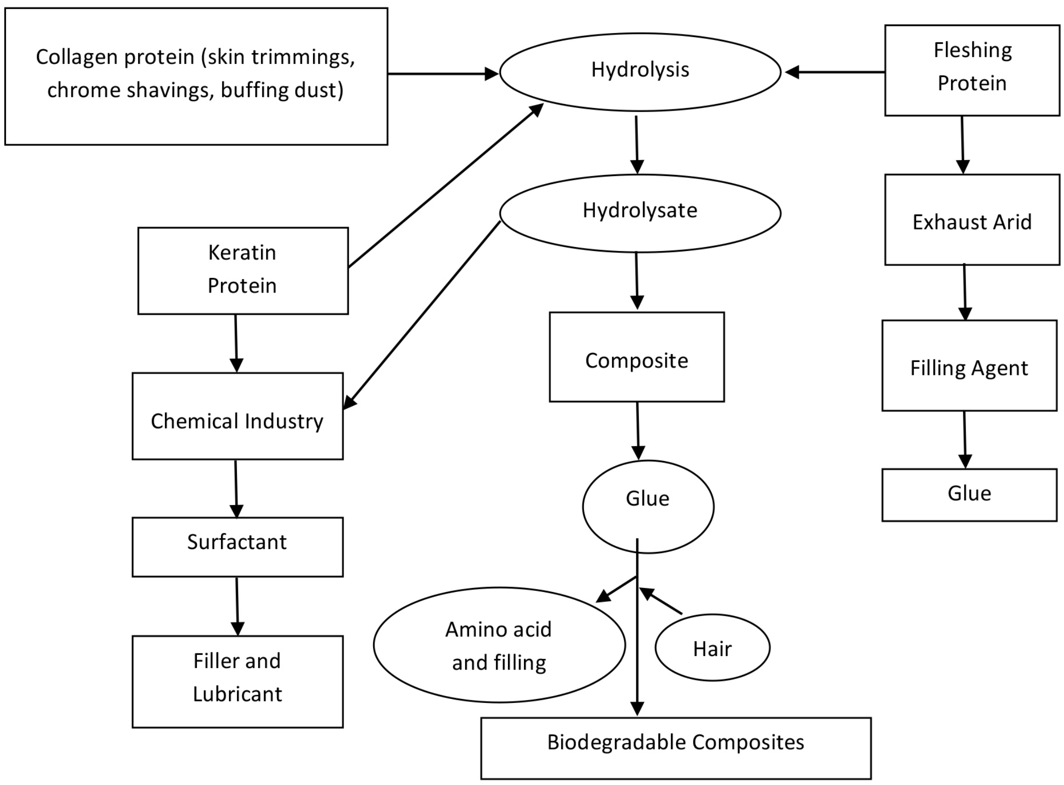


Figure 8: Treatment of tannery solid waste.

BSP 5.5 – ODOURS

- Promptly cure raw hides.
- Reduce the time that sludge remains in the thickener, dewater thickened sludge by centrifugation or filter press, and dry the resulting filter cake. Sludge containing less than 30% solids may generate especially strong odours.
- Curing and storage designed to prevent decomposition.
- Ventilate tannery areas and control exhaust from odorous areas (e.g. where waste water sludge is thickened and dewatered), through use of a biofilter and/or a wet scrubber with acid, alkali or oxidant.
- Replacement of ammonium compounds in deliming.
- Use handling and storage procedures designed to reduce waste decomposition.
- Control of pH followed by treatments to remove the sulphide content.

BSP 6 – WASTE MANAGEMENT

BSP 6.1 – WASTE MANAGEMENT PLANNING

Waste should be characterised according to composition, source, types of waste produced, generation rates or according to local regulatory requirements. Effective planning and implementation of waste management strategies should include:

- Review of new waste sources during planning, siting, and design activities, including during equipment modifications and process alterations, to identify expected waste generation, pollution prevention opportunities, and necessary treatment, storage and disposal infrastructure.
- Collection of data and information about the process and waste streams in existing facilities, including characterisation of waste streams by type, quantities and potential use/ disposition.
- Establishment of priorities based on a risk analysis that takes into account the potential environmental, health and safety risks during the waste cycle and the availability of infrastructure to manage the waste in an environmentally sound manner.
- Definition of opportunities for source reduction, as well as reuse and recycling.
- Definition of procedures and operational controls for on-site storage.
- Definition of options / procedures / operational controls for treatment and final disposal.

BSP 6.2 – WASTE PREVENTION

Processes should be designed and operated to prevent or minimise the quantities of waste generated and hazards associated with the waste generated in accordance with the following strategy:

- Substituting raw materials or inputs with less hazardous or toxic materials or with those where processing generates lower waste volumes.
- Applying manufacturing processes that convert materials efficiently, providing higher product output yields, including modification of design of the production process, operating conditions, and process controls.
- Instituting good housekeeping and operating practices, including inventory control to reduce the amount of waste resulting from materials that are out-of-date, off-specification, contaminated, damaged or excessive for plant needs.
- Instituting procurement measures that recognise opportunities to return usable materials such as containers and which prevent the over-ordering of materials.
- Minimising hazardous waste generation by implementing stringent waste segregation to prevent the commingling of non-hazardous and hazardous waste to be managed.

BSP 6.3 – RECYCLING AND REUSE

In addition to the implementation of waste prevention strategies, the total amount of waste may be significantly reduced through the implementation of recycling plans, which should consider the following elements:

- Evaluation of waste production processes and identification of potentially recyclable materials.
- Identification and recycling of products that can be reintroduced into the manufacturing process or industry activity at the site.
- Investigation of external markets for recycling by other industrial processing operations located in the neighbourhood or region of the facility (e.g. waste exchange).
- Establishing recycling objectives and formal tracking of waste generation and recycling rates.
- Providing training and incentives to employees in order to meet objectives.

BSP 6.3.1 - DUSTED SALTS

Dusted salts may be reused for pickling after dissolution in water and clarification or filtration. Alternatively, the recovered salts could be used for a number of applications including foundry casting (in the mould), hypochlorite production and de-icing of roads. Dusted salt can be reused for curing but a preliminary heat treatment is required to reduce bacterial impact and to limit the presence of organic matter in recovered salt.

BSP 6.3.2 - HAIR AND WOOL USE/DISPOSAL

Methods of hair-saving, i.e. preventing the hair from being released via the waste water stream, are discussed in 'Hair-save techniques' (see PI 1.3.1 - HAIR-SAVE TECHNIQUES). If there are no options for reuse, the hair has to be disposed of. In some cases, the hair is not separated and is sent for disposal together with the waste water treatment sludge.

Conventional lime sulphide treatment of hides/skins leads to pulping of hair; and as such, pulping leads to environmental problems if the pulping is not screened by using suitable mechanical means and prevented from entering the waste water stream. Hair constitutes 10-12% of the weight of the animal, which is also dependent o the season of the year; for instance, it is higher in winter. Wool constitutes 15-20% of the body weight depending on the breed and climatic conditions. The coarse hair and wool are collected, washed well, and used in carpet manufacturing. Hair could also be hydrolysed to produce fertilisers.

The hair residues from the unhairing step using hair-saving techniques are partially destroyed. Depending on rinsing and cleaning procedures, the chemicals from the unhairing step are attached to the hair. After washing, therefore, sulphides sometimes have to be removed by oxidation. Hair residues can be compacted to reduce volume before further treatment or disposal. The options for recycling and reuse of hair are summarised in Table 2. Hair can be used as a fertiliser because of the nitrogen content. Hair may also be landfilled after composting.

	Hair options
Uses as a by-product	Filling material
Reuse after preparation	Protein hydrolysate, brush from tail hair
Recycling as	Fertiliser
Other recovery	Generation of biogas by anaerobic digestion

Table 2: Options for dealing with hair

Sheep wool can be used by the textile industry, e.g. in carpet manufacture. Wool can also be composted together with other residues (although the temperature of spontaneous ignition has to be taken into account).

BSP 6.3.3 - TRIMMINGS

The smaller raw trimmings are collected, stored and sent to glue/gelatine and animal feed manufacturing units. The potential of hide collagen for human consumption as a food supplement has been explored by substituting wet or dry fibrous collagen in meat-based products. The utilisation of the collagen-rich hide and skin trimmings for the preparation of cosmetic hair-care formulations, for example, shampoos, perming lotion and bleaching aids, has been made possible.

The limed trimmings are proteinous in nature and found to be good raw material for glue, technical gelatine and animal feed. The limed trimmings are 2-7% of the wet weight of the hides.

The wet blue trimmings (estimated at 5.5-6% of the wet weight of hides) are collected from the tannery and utilised in the manufacture of leather boards and bricks, using a low pressure and temperature process to avoid oxidation of Cr^{3+} to Cr^{6+}. The use of chromed trimmings in fertiliser and leather meal applications is known. Chrome trimmings may also be de-chromed and processed into glue and commercial gelatine. The potential treatment of tanned trimmings is to produce collagen hydrolysate by biochemical hydrolysis which has enormous application in different fields, including the preparation of leather processing chemicals.

An overview of options dealing with raw, limed and tanned trimmings is given in the table below:

BSP 6.3.4 - FLESHINGS

Fleshings are produced either before (green fleshings) or after liming. The sulphide and lime content and the high pH from limed fleshings may reduce the acceptability of the residues in recycling facilities and make technical processing more difficult.

The availability of limed fleshing is 35% on the wet weight of the raw hides (70% moisture). The limed fleshing is collected by glue manufacturers and also by feed manufacturers. The composition of the limed fleshing is: moisture content 78-80%, ash content 8.3% and total nitrogen 15.2%.

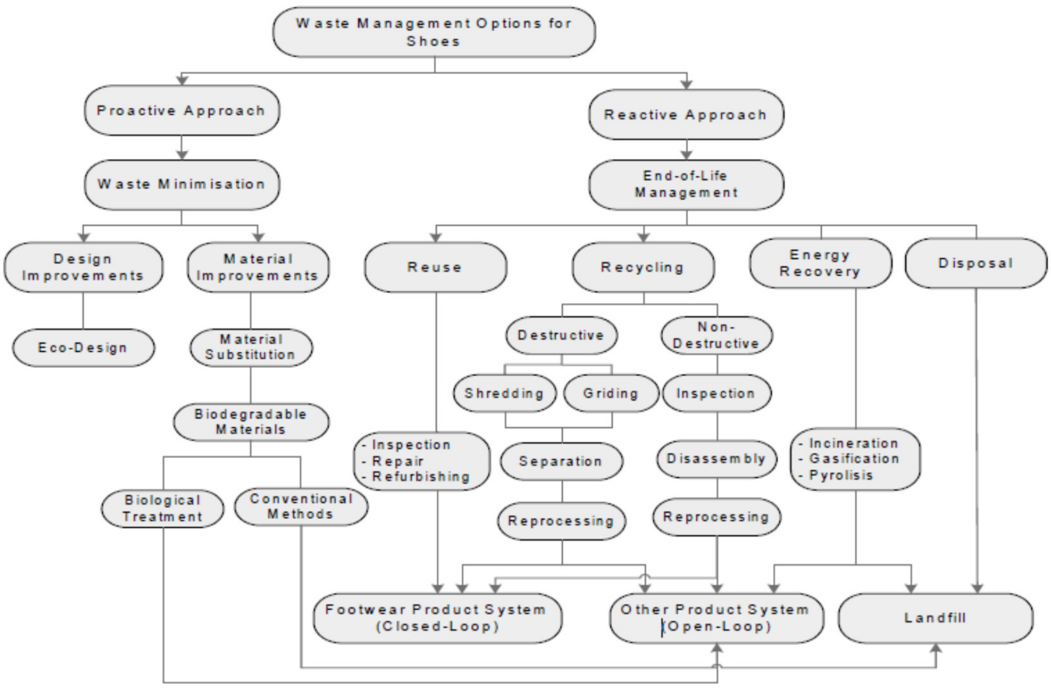


Figure 9: Waste management framework for footwear products. Source: The Centre for Sustainable Manufacturing and Reuse/Recycling Technologies (SMART).

The fleshing obtained by employing machines in tanneries is potentially thermally denatured. The utilisation of the same fleshing for glue manufacture is not economically viable. Similarly, fleshing obtained from hides treated with a high percentage of sodium sulphide is found to be unfit for the production of glue. They are best disposed through landfill. Disposal of such fleshing is currently a serious problem. Preparation of biogas or fuel from lime fleshing could be a better solution, but the cost effectiveness should be justified. Currently the best option for the treatment of lime fleshing is to produce dog chew after desulphurisation of the lime fleshing. Every tanner should have a treatment plant for lime fleshing either for the production of biogas or dog chew. A common lime fleshing treatment plant for the production of biogas could probably be a cost effective solution.

Options for dealing with fleshings are listed in the following table:

Uses	Types
Reuse after preparation	Protein hydrolysate, tallow
Recycling as	Hide glue
Other recovery	Generation of substitute fuel
	Generation of biogas by anaerobic digestion

Table 4: Options for dealing with fleshings

Limed fleshings should not be subjected to anaerobic digestion without pretreatment to remove sulphides, unless the digestion plant is designed to cope with hydrogen sulphide production. Animal health controls restrict the disposal routes for green fleshings.

Energy can be recovered from fleshings (in a mixture with some other residues) by the generation of biogas as a fuel *(see PI 5.1.4 – ENERGY RECOVERY FROM WASTE BY DIGESTION)* and the production of tallow as a fuel (*see PI 5.1.5 – ENERGY RECOVERY FROM WASTE BY COMBUSTION)*.

BSP 6.3.5 - SPLITS

The splitting process can be performed in either the limed or the tanned condition *(see PI 1.3.3 - PREVENTION OF H2S EMISSIONS FROM EFFLUENTS).* Depending on where the splitting takes place within the process line, further processing in different ways is feasible. Table 5 summarises the waste treatment options for untanned splits and for tanned splits together with shavings: composting and anaerobic treatment together with other waste fractions. Depending on the quality, untanned splits can be used to produce hide glue, gelatine and sausage casings.

	Untanned splits	Tanned splits
Uses as a by-product	Processed further to leather Production of sausage casings	Finished for use in patchwork, small leather goods, etc.
	Collagen production	Collagen production
	Dog chews	
Reuse after preparation	Production of technical gelatine	Leather fibreboard production (from non-finished materials)
	Protein hydrolysate	Protein hydrolysate
Recycling as	Hide glue	-
Other recovery	Generation of biogas by anaerobic digestion	-

Table 5: Options for dealing with untanned and tanned splits and trimmings

BSP 6.3.6 - SHAVINGS

Shavings are produced in different sizes. Many of the recycling routes available for shavings are the same as for tanned splits.

Chrome-tanned splits and shavings can be hydrolysed to produce chromium-containing sludge, fat and protein hydrolysate. Outlets have been found for the hydrolysate in various chemical and technical products.

Certain tanned leather residues are biodegradable, such as wet white shavings and vegetable-tanned shavings. This allows for a recycling route to produce soil improvers and fertilisers.
Energy is recovered from shavings in several Scandinavian tanneries.

Leather board is of softer texture than other fibreboards, but even in strength throughout its substance. Leather boards are essentially manufactured from waste leather scraps using a binder, generally rubber latex. An analysis shows that a leather board normally contains 75% leather, 10-15% rubber and the rest is moisture, fat and oils, etc.

The use of chrome shavings in the manufacture of leather boards, insulators, building materials, fibrous sheets and shoe soles has been established. However, presently the market for these materials has been replaced by synthetics. Hence, there is no demand for leather boards and shoe soles made from leather waste. The separation of chromium and valuable protein from chrome shavings through an enzymatic alkali process has also been reported. It has also been shown that chrome shavings can be used as a reductant in the manufacture of basic chromium sulphate (BCS). New parchment-like material from chrome shavings has been developed and found useful in the manufacture of home furnishing products. Chrome shavings can be used for the preparation of pigment through controlled incineration. Chrome shaving dusts can be used as adsorbent for the removal of toxic materials (heavy metals) in waste water.

The best solution for the treatment of shaving dusts is their biochemical hydrolysis to produce collagen hydrolysate which could be used in animal feed, fertilisers, biomethanation or as intermediate raw material for the production of re-tanning and finishing chemicals for leather processing. Ultra-pure collagen hydrolysate can be used in protein supplements or food additives, and in pharmaceutical and cosmetic industries.

BSP 6.3.7 - DUST FROM MECHANICAL FINISHING

Leather dust from milling and buffing operations is a waste for which a disposal route must be found. In most cases, the fine fibres contain tanning and post-tanning agents.

BSP 6.3.8 - FATS, GREASE AND OIL

Fats, grease and oil are by-products from hides or residual process chemicals from the process steps of degreasing and post-tanning operations, particularly from fatliquoring, as that is where they are separated from waste water effluents.

Grease from sheepskin dry degreasing can be recovered from the organic solvents and sold on the commodity market. The grease emulsions may be cracked if aqueous degreasing has been applied, either in solvent emulsion or in solvent-free emulsion using surfactants. However, no market has been identified for the grease recovered from the aqueous degreasing process with the use of surfactants.

Grease from hides is generally separated in grease traps. This grease has no commercial value. Fats and greases can be treated by anaerobic digestion. If these residues are not recycled or reused, they provide a good energy yield in thermal treatment and anaerobic digestion. Options for dealing with fats, grease and oil are shown in the table below:

Uses	Types
Reuse after preparation	Commodity market (grease from solvent degreasing)
Recycling as	-
Other recovery	Thermal treatment
	Generation of biogas by anaerobic digestion

Table 6: Options for dealing with fats, grease and oil

BSP 6.3.9 – LEATHER FIBRES

Leather fibres from uncoated leather can be used as a co-raw material in the manufacture of paper. Up to 10% of leather fibres can be added. At this level the leather has been found to improve the properties of the paper, particularly inter-fibre cohesion. Higher levels are difficult to process on simple equipment; in particular, it is difficult to remove water quickly due to the hygroscopic nature of leather. It is possible that in card manufacture higher levels of the leather could be used. The paper produced has an attractive appearance and could be niche marketed. The use of waste leather as a raw material is only economically feasible when the wood pulp price is high.

BSP 6.3.10 - DISPOSAL OF EFFLUENT PLANT WASTE

The main measures for minimising waste production in the effluent treatment plant are:

- Reduction of the input of process agents in order to decrease the effluent concentration and consequently the generation of sludge;
- Optimisation of the type and the amount of precipitation agents applied in the effluent treatment in order to reduce the amount of sludge;

- Separation of specific fractions of residues and different waste water streams for efficient treatment and production of lower amounts of sludge;
- Optimisation of the implementation of recovery and reuse measures aimed at reducing the amount of solid waste, waste water that has to be treated, and sludge;
- Keeping the sludge amounts as low as possible through selection of waste water treatment methods.
- Waste materials from effluent treatment consist of a small amount of course material and a large quantity of sludge of various kinds.

BSP 6.3.11 - DISPOSAL OF OTHER RESIDUES

Other residues require further (off-site) treatment, apart from the options discussed above for recycling and reuse in the process units themselves. These include the following residues: salt, organic solvents, and chemicals used as process chemicals, auxiliaries, cleansers, sludge from finishing stages, solids from air pollution abatement (activated carbon, sludges from wet scrubbers) and packaging material.

In order to minimise the environmental impact related to the residues, the following recommendations should be followed: *(Table 7)*

TECHNIQUE	DESCRIPTION	APPLICABILITY
Recovery of chromium for reuse in the tannery	Re-solution of the chromium precipitated from the tanning float, using sulphuric acid for use as a partial substitute for fresh chromium salts.	Applicability is restricted by the need to produce leather properties which meet customers specifications, in particular related to dyeing (reduced fastness and less brightness of colours) and fogging.
Recovery of chromium for reuse in another industry	Use of chromium sludge as a raw material by another industry.	Applies only where an industrial user for the recovered waste can be found.
Reduction of the sludge water content by using dewatering systems	Reduction of energy, chemical and handling capacity requirements of sludge for its subsequent treatment.	-

Table 7: Techniques to minimise environmental impacts related to residues

BSP 6.4 – TREATMENT AND DISPOSAL

If waste materials are still generated after the implementation of feasible waste prevention, reduction, reuse, recovery and recycling measures, waste materials should be treated and disposed of and all measures should be taken to avoid potential impacts to human health and the environment.

Selected management approaches should be consistent with the characteristics of the waste and local regulations, and may include one or more of the following:

- On-site or off-site biological, chemical or physical treatment of the waste material to render it non-hazardous prior to final disposal.
- Treatment or disposal at permitted facilities specially designed to receive the waste.

Examples include: composting operations for organic non-hazardous waste; properly designed, permitted and operated landfills or incinerators designed for the respective type of waste; or other methods known to be effective in the safe, final disposal of waste materials such as bioremediation.

BSP 6.5 – HAZARDOUS WASTE MANAGEMENT

Hazardous waste should always be segregated from non-hazardous waste. If the generation of hazardous waste cannot be prevented through the implementation of the above general waste management practices, its management should focus on the prevention of harm to health, safety, and the environment, according to the following additional principles:

- Understanding potential impacts and risks associated with the management of any hazardous waste during its complete life cycle;
- Ensuring that contractors who are handling, treating and disposing of hazardous waste are reputable and legitimate enterprises, licensed by the relevant regulatory agencies and following good international industry practice for the waste being handled;
- Ensuring compliance with applicable local and international regulations.
- Regarding waste storage, hazardous waste should be stored so as to prevent or control accidental releases to air, soil and water resources in a location where:
- Waste is stored in a manner that prevents the commingling or contact between incompatible residues, and allows for inspection between containers to monitor leaks or spills. Examples include sufficient space between incompatibles or physical separation, such as walls or containment curbs.
- Store in closed containers away from direct sunlight, wind and rain.
- Secondary containment systems should be constructed with materials appropriate for the waste being contained and adequate to prevent loss to the environment.
- Secondary containment is included wherever liquid waste is stored in volumes greater than 220 litres. The available volume of secondary containment should be at least 110% of the largest storage container, or 25% of the total storage capacity (whichever is greater), in that specific location.
- Provide adequate ventilation where volatile waste is stored.
- Hazardous waste storage activities should also be subject to special management actions, conducted by employees who have received specific training in handling and storage of hazardous waste:
- Provision of readily available information on chemical compatibility to employees, including labelling each container to identify its contents;
- Limiting access to hazardous waste storage areas to employees who have received proper training;
- Clearly identifying (labelling) and demarcating the area, including documentation of its location on a facility map or site plan;
- Conducting periodic inspections of waste storage areas and documenting the findings;
- Preparing and implementing spill response and emergency plans to address their accidental release;
- Avoiding underground storage tanks and underground piping of hazardous waste.

It is also noteworthy that on-site and off-site transportation of waste should be conducted so as to prevent or minimise spills, releases and exposures to employees and the public. All waste containers designated for off-site shipment should be secured and labelled with the contents and associated hazards, be properly loaded on the transport vehicles before leaving the site, and be accompanied by a shipping paper (i.e. manifest) that describes the load and its associated hazards.

BSP 6.6 – WASTE MANAGEMENT IN FOOTWEAR MANUFACTURING

In Europe, it is estimated that the amount of waste arising from post-consumer shoes could reach 1.2-1.5 million tonnes per year. The sector industries' contribution accounts for another 90,000 tonnes of waste derived from by-products and process rejects.

Footwear appears to be one of the key recycling targets of the future, considering that around 95% of the shoes purchased end up in the municipal waste stream. Nonetheless, footwear recycling and material recovery efforts continue to be hindered by (1) lack of well-established recovery systems and (2) incorporation of a variety of materials and chemical compounds into the same product that make recycling technology extremely challenging.

Effective management of EoL waste is a rather complex issue made up of many components. Although there is no blueprint that can be applied in every industrial sector, the European Commission has set up a waste hierarchy framework which specifies the order in which waste management options should be considered, based on environmental impact. Based on this hierarchy, an integrated waste management framework for footwear products has been developed and presented in Figure 9. This proposed framework divides the waste management options for shoes into two major approaches: proactive and reactive. Proactive approaches include all measures that are taken with the aim to reduce or minimise waste at the source. Reduction of waste, also referred to as Waste Minimisation, is a proactive approach because simply put, waste which is avoided needs no management and has no environmental impact. On the other hand, reactive approaches include all the other waste management options that act in response to the waste problem when the useful life of the product has ended. Reactive waste management approach is also referred to as End-of-Life Management.

Integrated waste management should be implemented and it is based on the 3R principle, i.e. 'Reduce, Reuse and Recycle'. Reduce means the reduction of materials and accessories for the production of footwear that will create minimum waste and ultimately reduce end-of-pipe waste treatment cost. Reuse means the materials and waste can be reused by the same user within the factory by preliminary treatment and separation. Recycle means that the discarded waste can be reused by other people rather than the original user. The strategy of the industry should be in the following manner for integrated waste management.

Many shoes end up finding a home in landfills when their trendiness expires. Many of these are still functional. 'Reuse a shoe' to recycle, reform and replace. Plasticised PVC is a widely used soling material but it faces several environmental challenges. PU sole-making is very toxic and the waste is not recyclable. Cutting waste can be used for making small leather goods, leather board and composite. Leather, thermoplastics and RIM PU, cotton textile, metallic pieces, solvents, oil, paper and cardboard waste can be recycled inside or outside the company.

Every area of the factory should have a colour-coded chart above the waste bins to indicate how the material should be separated when discarding. The workers can only discard one type of material in a specific colour bag. The disposed material is separated by category and then taken to the recycling facility. The recycling facility should have all the discarded materials separated by category as well. The colour-coded waste bags make it easier and faster to divide up the waste in the facility. To keep the facility running efficiently, cleanliness and organisation are extremely important.

The facility should be operated by an ecologist whose main motivation is to preserve the environment and increase awareness within his/her community. The staff members at the facility also teach art classes to instil in the children ways to reuse things before throwing them away. (The artwork is made from discarded waste.) The staff realises the importance of raise young people's awareness of the environment and their impact on it.

The quantity of waste generated in the shoe factory can be reduced in two areas, material scraps and packaging which is too small and too numerous. Special attention is paid to the production of scraps at an early stage. The finished product manufacturers are not aware of their cutting rates in leather. They only pay attention to the allocation ratio (for accounting, planning and purchasing purposes), which is quite different. The cutting rate refers to the real surface they throw away. The allocation rate is generally lower than the cutting rate as it is calculated on the basis of the relative surface occupied by a piece to be cut.

When they have the possibility to recycle the drums, some companies purchase their solvents and adhesives in larger metal packaging. This practice automatically reduces the quantity of packaging. The waste/packaging can be reused: cardboard boxes, empty thread cones and some tins. In order to reuse the cones and tins, the supplier must be in the same geographical area.

Incineration with energy recovery is a suitable solution for waste like leather, 'off-specification' materials, compounds which cannot be recycled, coated fabrics (multilayer material with/without PU foam) and 'off-specification' components or shoes. Special treatment is needed for hazardous waste which has no other solution available. Such residues are dried adhesive residues, bottoms of chemical packaging (used solvents, etc.), jars, tins and drums containing product residues (adhesive, etc.). When no solution can be applied for solid waste, the manufacturer has to consider landfilling. In most developed countries, landfilling is now considered the last solution, which should be applied to a small amount of waste. Now regulations generally require controlled land filling, which means that the landfill waste must be controlled and treated before being discharged to the environment.

Incineration must be carried out in a special furnace due to the toxicity of chrome-tanned leather. Before being introduced into the furnace, the leather residues are ground down to 10-12 mm. Then a special pneumatic feeding system introduces the scraps at the right place into the furnace. A fluidised bed is created by blowing air under pressure through sand set in the base of the combustion chamber. The upward flow of air via distributor plates set at the bottom of the bed creates movement, maintaining the grains in suspension. As the grains are continuously moving in the chamber, a constant temperature (400-500 °C) is easily maintained throughout the whole bed. A post-combustion chamber at 850 °C and an average dwell time of 2 seconds force the organic gases to burn completely.

Leather waste can also be recycled by acid digestion and thermal denaturation techniques for the preparation of fertilisers. A very strong acid (sulphuric acid) transforms the leather scraps into liquor. Then, the solution is mixed with an alkaline reactive (lime). At a neutral pH, the mixture becomes solid, like a powder. As it contains nitrogen and calcium, it can be applied on land for fertilisation purposes. The product obtained in the thermal denaturation process is a brown leather powder. The process involves thermal denaturation, a dryer (if using an autoclave) or a rotating roaster and a grinder. This powder can be used as an additive to fertilisers (addition of nitrogen).

Fibre and filler can also be produced from the leather scraps. The principle is to mix ground leather with a binder that can be thermoplastic (PVC, PE) or rubber. Leather fulfils both roles as a filler and a strengthener. Depending on the proportion of leather, binder and plasticiser, the compound can provide the feeling of real leather or plastic (for example, in heels for which a patent has been filed). Wall compound can be manufactured with up to 95% ground leather. Preparation of leather board from leather scraps is very economical and viable, with enormous uses in shoemaking such as for the insole, midsole, heel and even as an artificial leather upper.

Since leather contains 30-35% collagen, it is possible to produce gelatine after a physical/chemical reaction. After grinding, the leather scraps become digested in an acid or alkali solution with enzymes. From the resulting solution, a last step separates chromium from the collagen and produces industrial gelatine. Leather fibres from uncoated leather can be used as a co-raw material in the manufacture of paper. Up to 10% leather fibres can be added.

The main recycling technique applicable worldwide to textiles is the production of fibres. The principle is to use a high-speed rotating drum with nails. When touching this drum, textile pieces become transformed into fibres. Then it is possible to produce textile compounds, felts, etc. The common cases apply to cotton or wool for textile car upholstery, bed mattresses and water pipe insulation. TR, TPU and PVC residues that are not denatured (not burned) can easily be recycled within the company. Many experiments have been carried out by large PU suppliers in order to find a solution for RIM PU carrots, purges, etc. Before trying to recycle this waste, the first point again is to try to reduce their quantities. Two solutions can be industrially applied to RIM PU footwear, such as chemical recycling and recycling as a filler during the injection itself.

In chemical recycling, the PU scraps are ground and mixed with alcohol. After the chemical reaction (glycolysis), the recovered polyol is incorporated at a certain percentage (< 25% of polyol) to the fresh polyol during the production process. In recycling as a filler during the injection itself, the PU scraps need to be ground into small particles (< 3 mm). The PU powder can be incorporated at the injection head during production. This of course requires new injection equipment.

BSP 7 – OCCUPATIONAL HEALTH AND SAFETY

BSP 7.1- SAFETY INFORMATION ON CHEMICALS

According to the International Labour Organization, chemical container labels must include the following information:

- Trade name of the chemical
- Identity of the chemical
- Name, address and telephone number of supplier
- Hazard symbols
- Nature of special risks associated with the use of chemical

- Safety precautions
- Identification of the batch
- Statement that a material safety data sheet giving additional information is available with the tanner
- Classification assigned under the system established by the competent authority
- In addition, material safety data sheets should be requested from chemical manufacturers. These sheets must include the following data:
- Chemical product and company identification
- Information on ingredients/composition of the chemical
- Possible hazards classification
- First-aid measures
- Firefighting measures
- Measures in case of accidental release (e.g. spillage)
- Guidelines on handling and storage
- Information on how to control exposure and what personal protective equipment to use
- Physico-chemical properties of the product
- Security and reactiveness of the chemical
- Toxicological information
- Eco-toxicological information
- Guidelines on disposal
- Guidelines on transport
- Guidelines on classification and labelling
- Any additional information for the safety and health of the workers

Furthermore, safe working procedures should be available at the workplace. The aim is to provide useful, understandable information to the workers, in order to create a safe working environment.

BSP 7.2- CONTROL OF CHEMICAL HAZARDS

To a greater or lesser extent, workers are exposed to chemical hazards during:

- Loading, unloading and handling of chemical containers in the chemical store;
- Transfer of chemicals from containers in the chemical store;
- Mixing of chemical recipes in the chemical store or workplace;
- Transfer of chemicals from the chemical store to the workplace;
- Handling of chemicals in the workplace;
- Loading/unloading of raw material/pelt/ leather into/from pits, paddles, drums, machines;
- Removal of chemical waste and effluent from the workplace;
- Disposal of chemicals or effluent;
- Washing and disposing of chemical containers.
- It is necessary to avoid chemical exposure of workers, whether through inhalation, ingestion or skin contact. For safe handling of chemicals, several preventive measures must be taken.
- Eliminate, whenever possible, hazardous chemicals from the workplace, for example:
- Replace organic solvent-based chemicals with water-based chemicals in degreasing and finishing.
- Limit the chances of exposure to hazardous chemicals:
- Dose or transfer chemicals in fully or partly closed systems.
- Always put lids and covers on chemical containers.
- Use extraction systems on dry shaving, buffing, de-dusting, spraying machines and chemical weighing.

- Control discharge of floats from paddles and drums with a hose or gutter connected to the sewer.
- Use hand or motor pumps for transferring hazardous chemicals such as acids.
- Whenever possible, instead of spraying, use equipment such as roller coating, which produces less emission to air.
- Reduce the concentration of airborne pollutants using ventilation and natural airflow.
- Ensure good housekeeping practices, such as regular cleaning of work areas, floors, walls and machines, removal of waste and adherence to safe storing and handling practices.
- Reduce the number of workers in areas with hazardous chemicals and limit access to areas where hazardous chemicals are likely to be present (chemical store, effluent treatment plant, etc.).
- Reduce the exposure time, e.g. do all weighing at one time.
- As a last resort, prevent exposure to hazardous chemicals by the use of protective equipment.
- Gloves, boots and aprons should be available for every worker in the wet end of the tannery.
- Respirator-type masks with particulate filters and glasses should be used when handling powder and liquid chemicals.

BSP 7.3 - SAFE CHEMICAL STORAGE

When designing or implementing a chemical store, the following issues must be taken into account in order for the facility to be adequate and safe:

- Storage of chemicals should be separated from production areas, occupied buildings, other storage areas, workshop or areas with a potential source of ignition.
- The floor should be flat (for ease of handling) and non-permeable to prevent soil pollution.
- Emergency drains should be available and connected to the effluent treatment plant.
- It should have at least two emergency exits to allow easy escape for personnel.
- Electrical installations and other equipment for flammable chemicals should be 'explosion proof'.
- Natural and artificial ventilation should be provided at low and high levels.
- Access should be restricted to authorised, trained personnel.
- Firefighting equipment, e.g. ABC powder, should be kept ready in a suitable location, which can be easily and conveniently accessed in an emergency.
- A washbasin, eye/face rinsing station and safety shower should be available in or near the chemical store.
- In addition, the following organisational recommendations should be taken into account:
- Keep chemicals that will react together separated, e.g. acids away from sodium sulphide and alkali away from ammonium salts: any accidental mixing results in dangerous gas - H_2S, NH_3.
- Design and install pipes, valves, etc. in such a way that creates physical hindrances to incorrect addition or mixing of incompatible chemicals, e.g. from a tanker lorry into the wrong storage tank (acid into a sulphide solution).
- Group and store different chemicals according to their compatibility. For easier stock keeping, provide boards indicating name, maximum, minimum and current stock for each group.
- For maintaining better storage discipline, allot the specific storage areas for each group and mark the designated areas with yellow floor marking.
- Avoid storage of chemicals directly on the floor.
- Racks and shelves can store small containers such as dyes and fatliquor samples.
- Heavier chemical containers – particularly those containing liquid chemicals (e.g. acids) – should be stored on wooden or plastic pallets at the floor level.

- Barrels containing liquid hazardous chemicals must be stored in catch pits or in a walled area.

- Ensure sufficient width for movement of persons and materials (more than one metre for handling of chemicals, more than two metres for movement of pallets or forklifts).

- Whenever possible, solvents and other flammable or pyrophoric chemicals should be stored in a separate chemical room.

BSP 7.4 - SAFE CHEMICAL HANDLING

Training of workers

Training and education play important roles in the control of chemical hazards. People who work with chemicals should be aware of:

- The possible health risks caused by chemicals
- Safe working procedures
- Care and use of protective equipment
- Emergency and first-aid measures

Moreover, workers should be trained to identify when control measures fail and to interpret the labels provided on chemical containers.

Training is essential for new workers, and experienced workers should participate in regular refresher courses.

Basic rules and principles in handling chemicals
Workers must handle chemicals according to some basic rules:

- Never mix chemicals randomly and indiscriminately.

- Always add concentrated acid to water, never water to acid.

- Avoid breathing chemical fumes, dust or vapours using local exhaust ventilation. As a last resort use appropriate respirators.

- Avoid skin contact with chemicals. Use safety gloves and other personal protective equipment, as required by the applicable material safety data sheet.

- Wash hands with soap or other proprietary cleaner after handling chemicals.

- Wash off chemical spills on skin or eyes immediately with running water.

- Any chemical spillage should be reported to the supervisor, then cleaned up safely and without delay.

- For a large tannery, all chemicals should be distributed from a gangway located over the beamhouse, tanning and post-tanning drums. The gangway should be equipped with adapted tanks connected to the drum axle.

- For a small tannery, install a fixed funnel connected to the drum axle. Install steps to the funnel, which are not higher than 20 cm each. The upper edge of the funnel should not be higher than the hip of the worker when standing on the platform.

- Transfer of chemicals from chemical containers

- When transferring chemicals, the following rules should be taken into account:

- As a general principle, the quantity of chemicals at the workplace should be restricted to that required for daily or batch use.

- Make sure that the smaller containers used to transfer chemicals from the chemical store to the workplace are clearly labelled and marked.

- Take advantage of simple tools or arrangements such as hand piston pumps (e.g. for acids) or positioning of barrels on horizontal racks (e.g. for fatliquors).

- Do not use the same spoon, spatula, measuring cups for taking out different chemicals, to avoid contamination of chemicals.

- Avoid mixing and preparing chemical recipes in the work area. Ideally, designate a separate area in your tannery.

- Carrying of chemicals manually and in open containers should be avoided to prevent spillage, distribution of vapours and chemical accidents. Use closed containers, trolleys and pallet trucks.

BSP 7.5 - DISPOSAL OF CHEMICAL WASTE AND PACKING MATERIALS

Empty chemical containers can pose a safety risk and a health hazard when not disposed of properly. In order to minimise the environmental impacts related to chemical waste, the following principles should be applied:

- Remove empty chemical containers from the store and work areas.
- Safely store the containers in a separate area of your tannery.
- Do not pour or mix different waste chemicals into the same waste container or barrel.
- Returning empty containers back to the supplier for refill and reuse is an option to be promoted.
- Do not permit waste containers to be used for storing drinking water or food products.
- Waste chemicals should be collected and disposed of according to local regulations.

BSP 7.6 - OCCUPATIONAL HEALTH AND SAFETY REGARDING BIOLOGICAL HAZARDS IN TANNERIES

With regard to biological hazards, the following measures should be implemented:

- Inform workers of potential risks of exposure to biological agents and provide training in recognising and mitigating those risks;
- Provide personal protective equipment to reduce contact with materials potentially containing pathogens;
- Ensure that those who have developed allergic reactions to biological agents are not working with these substances.

BSP 7.7 – EMERGENCY PREPAREDNESS AND RESPONSE

In order to minimise the risk and potential consequences, an Emergency Preparedness and Response Plan should be prepared to cover the following:

- Planning Coordination - Procedures should be prepared for:
- Informing the public and emergency response agencies
- Documenting first-aid and emergency medical treatment
- Taking emergency response actions
- Reviewing and updating the emergency response plan to reflect changes, and ensuring that employees are informed of such changes
- Emergency Equipment: Procedures should be prepared for using, inspecting, testing, and maintaining the emergency response equipment.
- Training: Employees and contractors should be trained on emergency response procedures.

7 PROCESS IMPROVEMENTS FOR THE LEATHER SECTOR

7.1 TANNERIES

The main steps required for the production of leather are shown in the figure below:

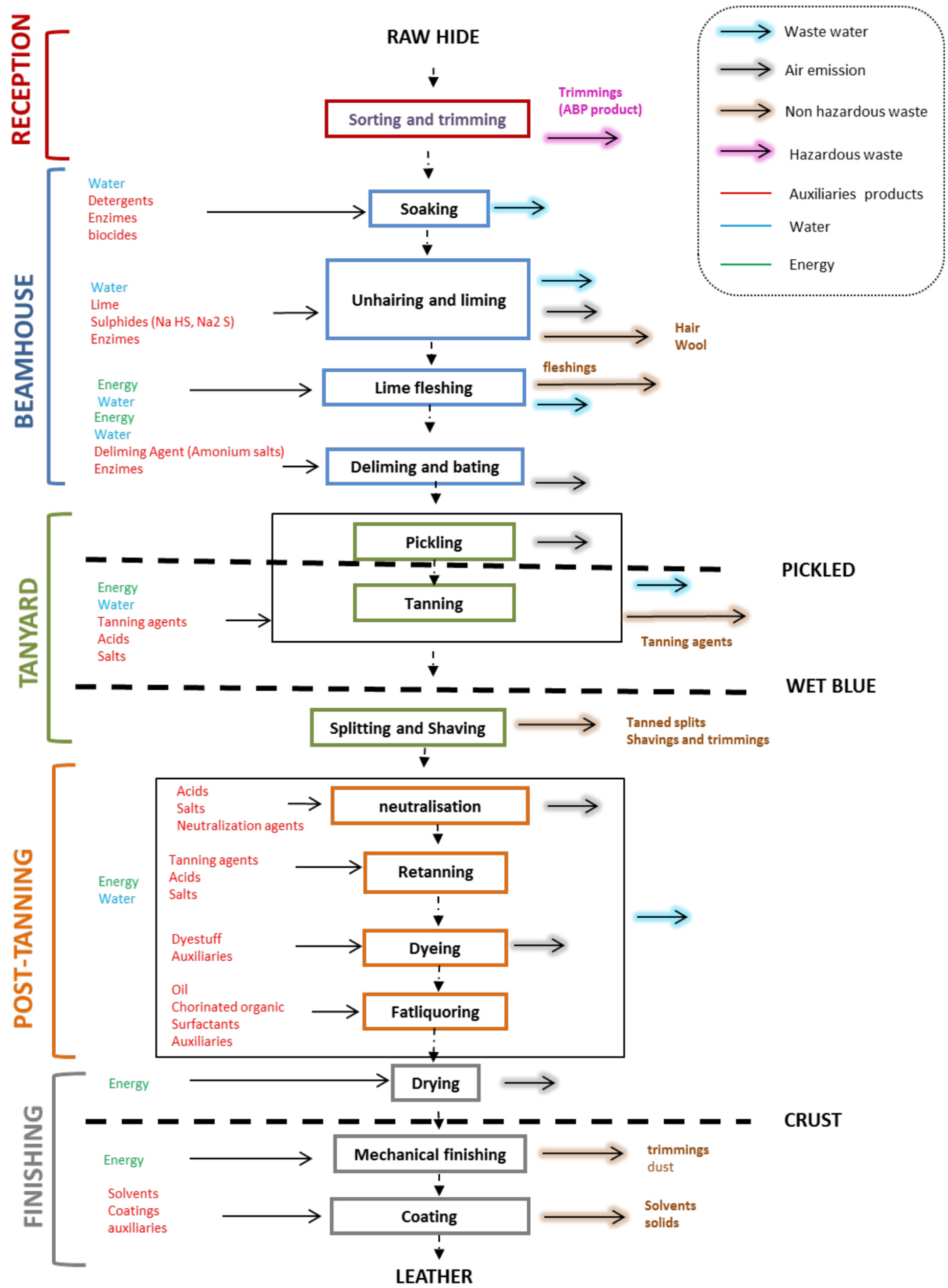


Figure 10: Tannery flowchart

PI 1 - BEAMHOUSE

PI 1.1 - CURING AND SOAKING

PI 1.1.1 - COOLING AND PROCESSING OF FRESH HIDES AND SKINS

Description

Chilling the hides and skins is considered a short-term preservation method, and is environmentally friendly for short storage periods. Chilling, based on reducing the hide temperature to 10–15 °C, has been used for many years, e.g. in Australia. If the refrigeration temperature is reduced to 2 °C, hides and skins can be stored for three weeks without suffering damage. The temperatures to which hides and skins should be chilled depend on the required duration of preservation.

There are advantages of processing cooled hides, which include:

- Under normal circumstances, there is no salt in the waste water from soaking;
- The quality of the hides is better; they are softer and have more regular neck parts, so they are easier to process;
- 1-1.5% better yield;
- Reduced soaking time.

Salt facilitates the elimination of some proteins and therefore some salt is added during the soaking process; enzymes can be used instead of salt to remove proteins.

Achieved environmental benefits

A reduction of nearly 100% of salt in the effluent from soaking is achieved.

PI 1.1.2 – USE OF ANTISEPTICS

Description

Suitable preservatives that are used around the world include: TCMTB, isothiazolones, potassium dimethyldithiocarbamate, sodium chlorite, benzalkonium chloride, sodium fluoride and boric acid. Their use must be regularly reviewed to reflect changing legislation, because they will be discharged in the effluent.

Some of these agents, which may have both bactericidal and fungicidal properties, are also appropriate for soaking, pickling and wet blue preservation.

Achieved environmental benefits

The use of antiseptics with low environmental impact and toxicity can help to increase the storage time of fresh or chilled hides and skins.

PI 1.1.3 - USE OF CLEAN HIDES AND SKINS

Description

This technique describes an arrangement whereby animals presented for slaughter have less manure adhering to the exterior of the hide or skin.

Several cooperation projects between tanneries and hide dealers took place between 1995 and 2000 with the objective of increasing the cleanliness of the hides delivered to the tannery and reducing the environmental impact.

Achieved environmental benefits

Apart from improving the quality standard of the leather there is less waste and a lower BOD of waste water.

Figure 11: Drum for desalting of hides. Source: UNIDO

PI 1.1.4 - REMOVAL OF SALT

Description

Through the application of this technique dry salted hides are opened out for processing in such a way that they are shaken or tumbled, so that loose salt crystals fall off and are not taken into the soaking process. Loose salt can be recovered by shaking. This operation can be carried out mechanically by using purpose-built equipment. Around 6–8% of the original salt content of the hide is eliminated, corresponding to about 5% of the total salt discharge from the tannery.

The reuse of salt might be problematic due to contamination (bacteria, organic material); the salt might be too dirty to be used in the pickle liquors without sterilisation with heat. Mechanically shaking off the salt can influence the quality of the hides, because the salt crystals can scratch or produce abrasion of the grain during drumming.

Achieved environmental benefits

The overall salt emission level is limited to the salt dissolved in the raw material. About 5% of the salt usually found in the effluent streams is recovered.

PI 1.1.5 – REUSE OF TREATED WASTE WATER IN SOAKING AND LIMING PROCESSES

Description

The aim of this technique is to enhance the treatment and storage of waste water for use in the early stages of processing. In this sense, the water from tanning and dyeing is treated in a sedimentation tank and utilised for soaking in the liming drum and as rinse water after liming.

The acidic waste water from tanning, retanning, dyeing and fatliquoring is treated mechanically and is subsequently alkalised and settled with the addition of polyelectrolytes and metal salts. The water thus treated is used in soaking. The rinse water from before deliming is reused for the first rinse stage after liming.
The second rinse water after liming is stored, sedimented and temperature-controlled in a tank and is used the next day as the first rinse.

Due to high organic and sulphide loading, the first rinse has to be treated and cannot be reused in the process.

Figure 12: Dome-type DODECA wooden frame for manual desalting. Source: UNIDO

Achieved environmental benefits

A savings of approximately 20% of total water consumption can be achieved by applying this water recirculation technique.
See BSP 3.1 - SUBSTITUTION OF OCTYLPHENOL AND NONYLPHENOL ETHOXYLATES.
See BSP 3.6 - ELIMINATING PESTICIDES FROM THE RAW MATERIAL (HIDES/SKINS).
See BSP 3.8 - SUBSTITUTION OF COMPLEXING AGENTS.

PI 1.2 - FLESHING

PI 1.2.1 – GREEN FLESHING

Description

The fleshing process is applied at an earlier stage of processing. Green fleshing is carried out either before any processing or immediately after soaking, as opposed to lime fleshing which is carried out after liming.

Fleshings can be sold to renderers, or the tannery may have a plant in which fleshings are processed to produce tallow. When deciding on whether to green flesh or lime flesh, it is important to take into consideration the specifications of the renderer or the capability of the on-site plant.

The basic machine for fleshing is the same for green fleshing and fleshing after liming. However, a demanuring cylinder has to be installed in order to remove manure from the hides prior to fleshing if green fleshing is carried out.

Achieved environmental benefits

The fleshings are free from liming and unhairing agents. Fleshing at this stage allows a more rapid and uniform penetration of chemicals into the hide.

If green fleshing is applied (and no repeat fleshing is needed) the consumption of chemicals and water in the beamhouse are reduced by 10–20%. Consequently, the waste water volume in the unhairing and liming step is reduced.

PI 1.3 - UNHAIRING AND LIMING

PI 1.3.1 - HAIR-SAVE TECHNIQUES

Description

Unhairing is carried out by dissolving the hair root rather than the whole hair. The remaining hair is filtered out of the effluent. The concentration of hair breakdown products in the effluent is reduced.

Hair-save processing has been developed for the processing of bovine hides in particular. The hair comes out of the follicle without being pulped and without destroying the hair shaft. A recirculation system with a screen is used to separate the intact hair. The recovered hair may become an additional waste stream, for which a use or disposal route must be found, rather than being discharged to the effluent. This brings about a reduction in levels of solids and BOD. Hair causes a very high organic load, which results in a high production of sludge.

The hair-save unhairing techniques use the difference in chemical behaviour between the proteins keratin and collagen. Collagen is the leather-making protein of the hide while keratin is the insoluble protein containing cysteine of which hairs and wools and the older (upper) layer are mainly composed of. Keratin is stabilised through disulphide bonds (-S-S-). The fully developed keratin in hair, nails and the upper part of the epidermal layer is highly resistant to chemical or biological attack, except from sulphide which breaks down the disulphide bonds. The resistance of keratin to chemical degradation can be substantially increased by immunisation: treatment with alkali but without sulphides. The alkali transforms the sulphur cross-links into different, highly resistant thioether bonds. Mature keratin is much more easily immunised than immature keratin. This increases the difference in degradability between hair and hair roots, thus simplifying the hair-save unhairing technique. Immunisation can be achieved by using sodium hydroxide, lime or calcium hydroxide and usually takes 1–1.5 hours. Most commercial systems for hair-save unhairing are based on immunisation.

Several commercial hair-save techniques are on the market. Although these techniques are not suitable for all types of raw hides and leather products, high-quality leathers are being produced. In Italy this technique is applied to bovine hides for footwear, leather goods and upholstery, but not to bovine leather used for the production of sole leather or to goatskin.

A hair-save technology for sheepskins, called painting, consists of the application of a semifluid paste on the flesh side of the skin, composed of an inert material (kaolin or other) containing sulphide and lime. The treatment is carried out in a warm environment (max. 30°C) and takes several hours. The painting of sheepskins is not further discussed in this section.

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 to be a cleaner technology if the hair is utilised, even as a nitrogen source. There are several established methods of hair saving, routinely used in tanneries. They do not provide a complete effect, since each incorporates a hair-dissolving step, to deal with residual short hairs.

Modern hair-save unhairing techniques use special equipment for recirculating the float and separating the hair. Hair separation is preferably carried out at the same time as hair loosening, so as to minimise the degradation of the hair. Drums equipped with recirculation as well as temperature and pH regulation are commercially available. The float is pumped out of the drum box and fed back in again through a hollow axle. A recirculation and filtering system can be fitted on existing drums provided that the drum axles can be used for float circulation. Another solution is filtration, after collecting the drained float in a pump sump and collecting the filtered float in a tank, where it can be pumped back to the unhairing vessels. In this case, it is possible to use one filtering unit for several vessels.

Achieved environmental benefits

Environmental benefits which may be achieved by the use of the technique are:

- A reduction of organic loads in the waste water;
- A lower volume of sludge for disposal or treatment;
- Savings on waste water treatment chemicals.
- The following table shows the emission reductions achieved using hair-save technology, whether or not in combination with recycling and filtering the float:

Discharge from hair-save unhairing (1)		% reduction compared to hair-destroying unhairing	
Emission parameter	Kg per tonne of raw hide	In unhairing liquor (1)	In total tannery waste water
Total solid	60	30	8
Suspended solids	15	70	43
BOD_5	20	50	28
COD	50	50	28
Nitrogen (TKN)	1.5	55	22
Ammonium nitrogen	0.2	25	2
Sulphide (S^{2-})	0.6-1.2	50-60(2)	50-60(2)

Table 8: Reduction of emission from hair-save unhairing compared to hair-destroying techniques

(1) Including waste water from washing
(2) The percentage reduction of the discharge is greater than the corresponding reduction of the dosage

PI 1.3.2 - REDUCING SULPHIDE CONSUMPTION (LOW-SULPHIDE UNHAIRING)

Description

Through this technique the amount of inorganic sulphide used in unhairing is reduced by substituting organic sulphur compounds or enzyme preparations for part of the requirement.

A total substitution of the sulphides used as an unhairing agent is currently not possible in practice, but their use can be reduced considerably. In ovine skins, the necessary upgrading of the wool as a by-product hinders the reduction in the sulphide consumption for the unhairing operation.

A number of organic sulphur compounds including thioglycolate, thiourea derivatives, in particular mercaptoethanol, are used in commercial unhairing systems. All types are strong reducing agents, acting in the same way as sulphides. The advantage of their use is that they considerably reduce the amount of sulphides consumed and discharged with the waste water.

Enzymes and amines can be added to facilitate the unhairing and reduce the consumption of sulphides. Combinations of enzymes with sulphides are used to make the hair removal more efficient. The hair has to be removed continuously to prevent it from dissolving in the float. The use of enzymes in this technique may lead to damage to the grain surface.

For ovine skins, the partial replacement in the painting process of sulphides by thiols, amines or enzymes is not possible.

Achieved environmental benefits

The consumption and discharge of sulphides to the waste water using commercial low-sulphide systems are reduced by 40 – 70%.

PI 1.3.3 - PREVENTION OF H2S EMISSIONS FROM EFFLUENTS

Description

Effluents from the unhairing and liming processes contain high concentrations of sulphur compounds derived from the sodium sulphide used in unhairing. If the pH of these effluents is allowed to fall below 9.5, hydrogen sulphide gas is evolved. These liquors may be oxidised (biologically or by adding chemicals using manganese sulphate as a catalyst) before being mixed with acid effluent or being discharged to the general mixing tank which generally has a pH of 8.5–9.

It is common practice to treat sulphide-bearing effluents from the beamhouse separately to reduce the sulphide levels in the waste water treatment plant, and in order to prevent the release of hydrogen sulphide when acidic effluents are mixed with effluents containing sulphide.

If sulphide-bearing effluents are to be mixed with acidic or neutral effluents before full oxidation of the sulphide is achieved, the mixing must be carried out in an enclosed tank, with air extraction through either a carbon filter or a scrubber dosed with either hydrogen peroxide or alkaline sodium hypochlorite.

Achieved environmental benefits

Prevent the release of hydrogen sulphide from effluents.

PI 1.3.4 – DIRECT RECYCLING OF LIMING FLOAT

Description

The quality of the leather produced can be affected negatively through this recycling process, unless the unhairing and opening up processes are used in two steps. This is because the suspended melanin and undissolved cuticle fragments from the dissolved hair (referred to as scud) are driven into the grain by mechanical action, making it dirty.

This cleaner technology is industrialised in several large bovine tanneries for shoe upper leather. The success depends on how the hair is removed and how well the recycled liquors are cleaned up before they are recycled.

Achieved environmental benefits

Resulting advantages are savings in sodium sulphide (up to 40%) and in lime (up to 50%). It can give a decrease of 30-40% of the COD and 35% of the nitrogen for the mixed effluent.

PI 1.4 - SPLITTING

PI 1.4.1 - LIME SPLITTING

Description

The objective of lime splitting is to carry out the splitting operation at an earlier stage of processing, so as to produce an untanned by-product.

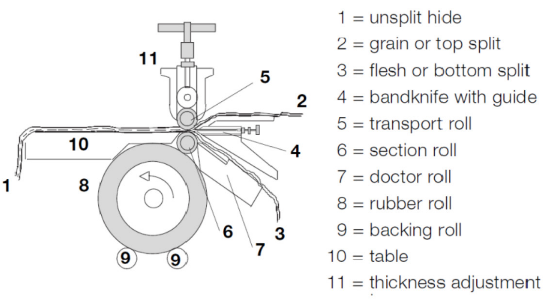


Figure 13: Operating principle of splitting machine. Source: UNIDO and BASF

Splitting is a mechanical operation, in which the hide is divided horizontally into an outer 'grain' and a flesh layer (sometimes even a middle layer). The splitting can be done either after liming (lime splitting) or after chromium tanning, in the wet blue condition.

In many cases, the splitting of limed hides is more environmentally friendly than splitting after tanning (blue splitting).

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

Lime splitting has several advantages compared to the splitting of either tanned or crust materials:

- The area yield is improved compared with blue splitting due to maximum relaxation of the grain surface;
- Chemical consumption in subsequent wet processes is reduced;
- Processing time is reduced, due to a reduction in the overall thickness of the leathers;
- There is flexibility to carry out different tannages on split and grain layers.

On the other hand, limed pelts are more difficult to handle than either tanned or crust leathers, and the accuracy of lime splitting is not as high as can be achieved by splitting tanned stock. Another disadvantage is the fact that handling a pelt in the limed state with a pH of 12 requires more safety precautions than handling wet blue pelts.

Bovine hides used for the production of either upholstery or automotive leathers are typically split in limed condition. The resultant split will have an uneven surface due to differential swelling during the liming operation, and will need additional shaving to achieve the desired final thickness.

The flesh split from lime splitting can be used either for processing into leather or for the manufacture of collagen products (gelatine split: gelatine, food casings, and dog chews). Regulations may limit the use of green and limed splits if they contain bactericides, enzymes or chemicals other than sulphide and lime.

Splitting at more than one stage of production requires different splitting machines to be installed.

Figure 14: Splitting machine. Source: UNIDO

Achieved environmental benefits

The consumption of all chemicals and water in the subsequent process is reduced, because only the parts of the hides processed into leather are treated. Savings in chemicals per square metre of leather produced in the process between liming and shaving are directly proportional to the weight of the lime split waste.

PI 1.5 - DELIMING AND BATING

PI 1.5.1 - SUBSTITUTION OF AMMONIUM COMPOUNDS BY CO2

Description

Carbon dioxide deliming is generally regarded as a practicable technique that can considerably reduce the environmental impact of this operation. A partial or complete substitution of ammonium salts used as deliming agents is possible for bovine hides.

Carbon dioxide dissolves readily in water, forming carbonic acid (weak acid), which causes the desired gradual reduction in pH of the hides. The way the CO2 is introduced into the float depends on the type of vessel used. In suitable drums, CO2 can be injected in gaseous form through the gudgeon, or preferably, if the drum is equipped with a recirculation device, the CO2 can be added there to ensure better mixing. In mixers, the CO2 is introduced directly by a lance. In pit-type vessels, the CO2 is mixed in by a sparger pipe.

If sufficient deliming cannot be achieved using CO2 alone, reduced quantities of ammonium salts or ammonium-free deliming agents, such as weak acids or esters can be used. However, in comparison to deliming with CO2 alone, the resulting COD is higher, due to the contribution from the reagent. Cost and slowness of reaction make them less viable.

Releases of H_2S can be prevented by the addition of hydrogen peroxide (0.1–0.2%) or sodium hydrogen sulphite. However, sodium hydrogen sulphite releases sulphur dioxide. Hydrogen peroxide can be corrosive to wooden drums. A system for automatic stoichiometric dosage of hydrogen peroxide has been developed, said to prevent both H_2S generation and surplus H_2O_2 in the drum. Treatment of extracted air can abate odour problems.

If the pH falls below 7, black or red hides may appear dirty due to the retention of melanin in the depleted grain layer. If the pH of the CO_2 deliming float is lower than that obtained using ammonium salts, special bates can be used. Also, bates with a lower content of ammonium are available.

The advantages of applying gaseous carbon dioxide are that little process control is necessary and the gas is easily injected into process vessels. If CO_2 is used in the deliming, the final pH at the end of the process can be somewhat lower (pH 6.7–6.9) than when using ammonium salts (pH 8.8–9.2). Careful control of carbon dioxide deliming can allow the pH at the end of the process to be between 8.8 and 9.2. If the pH at the end of the deliming process is below or above the pH recommended for optimal activity of conventional bating enzymes, the subsequent bating step may require adaptation by using different bating enzymes with optimal activity in the lower pH range.

Generally, the deliming time has to be extended. For thick, unsplit hides, accelerating auxiliary agents are available, or a small amount of ammonium salts or organic acids can be added.

The quality of the final product may not be affected for most uses, but some tanners report stiffening of the leather. The amount of chemicals used will decrease. A disadvantage with conventional deliming is that acid is added in concentrated form, which causes a localised pH drop, forcing open the pores and making the finished hide much coarser. The use of carbon dioxide eliminates this effect, as it does not cause a sudden drop in the pH, since it is added in small doses either continuously or intermittently, thus reducing the pH gradually to the desired level. The result is a cleaner hide with no enlarged pores. The reduced coarseness means that the colour bonds better in the dyeing stage. Carbon dioxide deliming also improves the degreasing action, which may result in less detergent being used in the process or the use of milder detergents.

Achieved environmental benefits

CO_2 deliming can reduce nitrogenous discharges. In comparison to conventional techniques, with ammoniacal nitrogen emissions of 4–5 kg per tonne of raw material, with carbon dioxide deliming, ammoniacal nitrogen levels of 0.,02 kg per tonne of raw material can be achieved. A 20–30% decrease in total Kjeldahl nitrogen emissions and a 30–50% reduction in BOD in the effluent from the tanning process are possible. The release of gaseous ammonia from the deliming process can be reduced or eliminated.

PI 1.5.2 - SUBSTITUTION OF AMMONIUM COMPOUNDS BY ORGANIC ACIDS

Description

Magnesium lactate, organic acids such as lactic acid, formic acid and acetic acids, or esters of organic acids can be used to substitute ammonium compounds in the deliming process. The advantage of substituting ammonium salts is that ammonia levels in the waste water are reduced.

Achieved environmental benefits

Environmental benefits which can be achieved using this technique are a reduction of nitrogen in the effluents and a reduction of gaseous ammonia releases during deliming.

PI 2 - TANYARD OPERATIONS

PI 2.1 - PICKLING

PI 2.1.1 - SALT-FREE AND REDUCED SALT PICKLING

Description

Salt-free systems, based on non-swelling polymeric sulphonic acids are available. The possibility of a partial substitution of chloride, e.g. by using aromatic sulphonic acids, has also been reported.

Achieved environmental benefits

The discharge of chloride and sulphate salts is reduced to about 1 kg/t raw hide.
See BSP 3.1 - SUBSTITUTION OF OCTYLPHENOL AND NONYLPHENOL ETHOXYLATES.
See BSP 3.2 - SUBSTITUTION OF HALOGENATED ORGANIC COMPOUNDS IN DEGREASING.

PI 2.1.2 - OPTIMISING THE USE OF ORGANIC SOLVENTS IN THE DRY DEGREASING OF SHEEPSKINS

Description

Various chlorinated solvents, such as chlorinated aromatic and aliphatic compounds, are applied for degreasing wool-on sheepskins. Toxicity, flammability, explosion prevention, and releases to air (VOC) and soil are the major points of concern, with the emphasis depending on the particular solvent or the mixture of solvents used.

The dry degreasing process of wool-on skins is usually carried out in closed machines with abatement measures for air and waste water releases (e.g. activated carbon filters) and the used solvent is automatically distilled and reused. However, there will always be fugitive emissions. A certain amount of halogenated organic solvent can be recovered, but there will always remain a residue (hazardous waste) of grease, solvent and water which will always be very difficult to treat further.

The distillation can be easily performed if there is only one organic solvent applied, but it gets increasingly difficult, or even impossible, to recycle mixtures of organic solvents.

Achieved environmental benefits

Over 80% of organic solvent can be recovered with closed-loop systems. Residues can be collected for further processing as, e.g. the production of tallow or fatliquors for the leather industry. If the equipment used for degreasing is properly designed and maintained, it is possible to have either no emissions of organic solvents or very low emission levels.

PI 2.2 - TANNING

PI 2.2.1 - INCREASING THE EFFICIENCY OF CHROMIUM TANNING

Description

The aim of this technique is to optimise the physical parameters of the process to increase the proportion of the conventional chrome tanning agent taken up by the hides or skins.

The chromium uptake in the hides depends on many factors. Helpful measures can therefore be taken in previous process steps. For example, a thorough liming produces more groups where the chromium complex can be bound. Splitting after liming facilitates chromium penetration and reduces chemical input *(see PI 1.4.1 - LIME SPLITTING).*

The next step is to ensure high efficiency in the process. The conventional chromium tanning carried out in long floats is characterised by poor exhaustion, with 30–50% of the chromium applied being lost with the waste water. It has also been reported that an average of 40% of the chromium input may be discharged.

The chromium exhaustion in conventional tanning systems can be improved by the following process changes.

- The chromium input must be optimised during conventional chrome tanning to reduce the possible waste (lowest chromium offer possible should be used).
- Processing parameters, e.g. pH and temperature, must be optimised to increase chromium uptake (end values of above 50 °C and pH 4 are advantageous, if compatible with good leather properties). Tanning cannot start at a temperature higher than 30°C. The float temperature can be increased only progressively, during the tanning step, from the room temperature to the final one.
- Short floats reduce the chromium input, combining a low chromium input with a high chromium concentration.
- Enough time must be allowed for penetration and reaction of the chromium with the substrate (a long process time).

Achieved environmental benefits

- Without introducing any new chemicals or techniques, tanners can significantly improve the chromium uptake (compared to about 60% in normal operation):
- 70–80% chromium uptake can be achieved by altering the physical parameters (temperature rise from 20 °C to 50 °C, pH from 3.5 to 4.5) of the tanning operation;
- Up to 90% chromium uptake by altering both physical and chemical parameters (float levels, chrome offers).

A reduced chromium discharge from the tanning process will lead to a lower amount of chromium in the sludge generated during waste water treatment.

PI 2.2.2 - HIGH-EXHAUSTION CHROMIUM TANNING

Description

High-exhaustion tanning includes the use of specific chemical products able to increase the chromium uptake combined with an optimisation of the tanning process parameters. There are two types of high-exhaustion systems:

In the first type, certain reactive groups are incorporated into the chrome tanning complexes. Chromium is reacted with dicarboxylic acid to form complexes of a suitable size for cross-linking.

In the second type, the collagen reactivity may be increased by increasing the number of carboxyl groups on the amino acid side chain in the collagen structure of the hides, in order to provide more sites for cross-linking. There are special agents (aromatic dicarbon acids, e.g. of adipic or phthalic acid, aldehyde carbon acids, e.g. glyoxylic acid), which enhance the number of links available for the binding of chromium in the collagen structure.

Achieved environmental benefits

The principal environmental benefit which can be achieved by the use of high-exhaustion chromium tanning is a reduction in the emission of chromium compounds in the waste water. A comparison of those emissions with those from optimised conventional chromium tanning is shown in the table below:

Units per tonne of hide or skin		Short float chromium tanning and good management	Salt-free pickling high-exhaustion chromium tanning
Water volume	m^3/t	1	0.5
Total solids	kg/t	150	80
Suspended solids	kg/t	7	7
BOD_5	kg/t	3	3
COD	kg/t	7	7
TKN	kg/t	1	0.5
Ammonium nitrogen	kg/t	0.5	0.1
Chromium (Cr)	kg/t	5.2	0.1
Chloride (Cl^-)	kg/t	60	28
Sulphate (SO_4^{2-})	kg/t	30	16
Grease and oil (may be higher when fatliquor is added to the float)	kg/t	1.5	1.5

Table 9: Emission in waste water per tonne of raw hide from the chromium-tanning process (including pickling)

The concentration of chromium in effluent treatment sludge is also reduced.

PI 2.2.3 - RECYCLING AND REUSE OF CHROMIUM SOLUTIONS

Description

Exhausted tanning floats are reused at either the pickling or tanning steps. There are two options for the recycling of exhausted tanning liquors:

Recycle the tanning liquors to the pickling process

If tanning is executed in the pickle float, the exhausted tanning bath can only partly be recycled into the next batch of pickle liquor. For recycling into the pickling float, the liquor is passed through a nylon screen and, after 24 hours, passed to a tank where it is mixed with the pickle acid. The hides are drummed in a brine solution, and then the pickle/chrome liquor is added. After the standard pickling time, the fresh chromium input is added.

Recycling the tanning liquors to the tanning process

If the liquors are recycled to tannage, hides are taken out of the drums at the end of the process, allowing about 60% of the float to be recovered. In the tanning operation, fresh chromium powder is added to the drained pickled pelts (which carry about 20% residual float) and then the recycled liquor is added.

In both cases some changes to the tanning process might be necessary, such as reducing the amount of masking agents and salts added. For both options, a holding tank and a screening of the solutions are required. Recycling up to 10 times before discharge is possible. Chromium liquor builds up volume (instead of discharging to the environment).

Process control and monitoring are necessary for calculating and adjusting float strength (salt content, pH, etc.) and for checking impurities.

Achieved environmental benefits

The efficiency of the recycling is dependent on the efficiency of the tanning process itself:

Recycling the tanning liquors to the pickling process

On average, 50% of the tanning float (but not the drainage water and the water from samming) can be recycled, which is equivalent to up to 20% of the fresh chromium input.

Salt carried over in the spent tanning liquor allows for a reduction of 40% in the salt added to the brine solution.

Chromium discharge in the effluent can be reduced by 50% (reduction of 40–50% from 5.9 to 2.8–3.5 kg Cr per tonne of raw hide in the waste water.

Recycling the tanning liquors to the tanning process

The fresh chromium input can be reduced by 25% for bovine hides and up to 50% for sheepskins. Chromium discharge in the effluents can be reduced by 60%.

PI 2.2.4 - CHROMIUM RECOVERY THROUGH PRECIPITATION AND SEPARATION

Description

Separation of chromium salts from the aqueous effluent stream by precipitation, with dewatering of the precipitate. Re-solution of the precipitated chromium using sulphuric acid, for use as a partial substitute for fresh chromium salts, or use of the chromium sludge as a raw material by another industry.

The technique is used for the treatment of effluents from the chromium-tanning process including washing floats and liquid from samming. It is based on the recovery of chromium from the effluents and its recycling into the production process.

From the chemical point of view, chromium(III) recovery is a simple process with excellent environmental results, but it needs careful analytical control and it requires special equipment such as:

- A separate tank for collecting spent chrome tanning liquors
- Material to analyse the chromium content, acidity, and alkalinity
- A tank with stirrer and ph control for adding the right amount of alkali for the precipitation
- A sedimentation tank for chromium hydroxide settling
- A filter press or centrifuge for the chromium hydroxide sludge
- A tank with stirrer and heating equipment for the re-solution of the chromium hydroxide by concentrated sulphuric acid.

When a double precipitation is needed, using fossil flour to absorb fats and other chemicals present in the spent chromium tanning liquors, more filter presses, more chemicals, more time, and higher costs are involved.

Chromium(III) can be recovered from the exhaust liquors (tanning liquors, samming water) from the conventional chrome tanning process; chromium from high-exhaustion chromium salts is not recycled due to the low concentration. The liquors containing chromium are collected in a collection tank, after which the chromium is precipitated by addition of an alkali. The precipitated chromium is separated from the supernatant, after which the chromium sludge is dissolved in concentrated sulphuric acid (for 1 kg Cr_2O_3 as precipitate about 1.9 kg H_2SO_4 is required). The supernatant is generally discharged to the effluent. The precipitate should be re-dissolved as soon as possible, as it becomes less soluble with time.

Any alkali will precipitate chromium, but the stronger the alkali, the faster the rate of coagulation. One of the precipitation options given below can be selected.

- Sodium hydroxide or sodium carbonate (as strong alkali) will lead to a fast precipitation and voluminous sludge.
- Fast precipitation with additional agents like polyelectrolytes to facilitate coagulation has the advantage that only simple dewatering is necessary.
- Slow precipitation, e.g. magnesium oxide (as a powder, pH 8), gives a denser sludge, which allows for decanting. For 1.0 kg Cr_2O_3 in the spent liquors, 0.25–0.4 kg MgO is needed depending on the basicity and masking. Another advantage of the use of MgO is that any excess addition will not cause the pH to rise beyond 10, so that any sludge re-dissolving at higher pH levels is avoided.

Impurities and process chemicals may build up and therefore an increased level of process control is needed, and impurities may need to be destroyed after dissolving the chromium sludge.

Achieved environmental benefits

Efficiencies of 95–98%, 99% and 99.9% of chromium precipitation are reported. In the Netherlands, reported values are 1–2 mg Cr/l, measured as total chromium in a daily composite sample, after sedimentation or flotation of the separate chromium-containing effluent before mixing. The same levels are achieved in some German tanneries. A tannery in Sweden normally achieves chromium concentrations of < 1 mg/l in the separated effluent containing chromium after precipitation. The discharge to the treatment plant after this internal measure is about 0.4 kg chromium per tonne of raw hide. Most of the chromium in the discharge to the waste water comes from the post-tanning operations (retanning, dyeing and fatliquoring) and these effluents are not passed through the chromium recovery unit.

Data from tanneries in the UK show chromium contents of 3000–6000 mg/l in the chromium liquors after tanning. Chromium precipitation can remove around 99.9% of this chromium, which results in a concentration of chromium in the separated effluent of 3–5 mg/l and a concentration in the total effluent following mixing with beamhouse effluent of less than 1 mg/l.

The recovered chromium sulphate solution can be recycled into the tanning process by replacing up to 35% of the 'fresh' added chrome tanning salt.

As the overall chromium utilisation ratio increases, the amount of chromium discharged to the waste water is reduced. This results in a reduction of chromium in sewage sludge and chromium discharged to the environment. No additional waste volume is built up.

PI 2.2.5 - PRETANNING WITH NON-CHROME TANNING AGENTS

Description

Pretanning changes the physical and chemical characteristics of the leather and can be used as a mechanism to improve chromium uptake or reduce the input of chromium. The pretanning agents are aluminium salts, sometimes aluminium combined with polyacrylates, glutaraldehyde derivatives, syntans, titanium salts, or colloidal silica. The minimum dosage is 1.25% aluminium oxide, 1.0–1.5% glutaraldehyde or 0.75% titanium oxide.

Certain pretanning recipes can be combined with non-chromium tanning agents to produce chromium-free leather. It is believed that if a pretannage is applied and the physical parameters for chrome tanning are well controlled (temperature up to 60 °C, basify up to pH 4.2), the chromium input can be reduced from 8 to 5% on the basis of limed weight.

Some pretanning agents can raise the shrinkage temperature of the collagen significantly. Pickling and pretanning can be combined, although pickling is not always necessary. Depending on the selection of tanning agents, pretanning can be performed without noticeably changing the characteristics of the leather, in order to be flexible in the choice of further processing. Pretanning can be followed by different tanning processes, such as chrome tanning, vegetable tanning or resin tanning.

Achieved environmental benefits

Pretanning with non-chromium agents can be used to improve the chromium uptake and reduce the chromium input, although the environmental impact of the pretanning agents must be carefully assessed. For example, aluminium carries higher environmental risks than chromium, because of its higher solubility.

Exhaustion in subsequent chrome tanning is enhanced from 93% to 97%. In one case, the subsequent chromium dosage was reduced from 15 kg Cr per tonne of raw hide in conventional tanning to 6.5 kg Cr per tonne of raw hide. However, the price of this improvement is the need to input pretanning agents.

An advantage is that only the leather needed for the final product is tanned and the input of tanning agents is therefore reduced. The residues (or by-products, with market value) produced from splitting and shaving (shavings, particulate matter) after this pretanning step are chromium-free, which in some cases is advantageous for reuse, recycling and disposal of the waste.

The shavings and trimmings, as they are basically organic materials, have proved to have excellent value as fertiliser, equal to that of chromium-tanned shavings and trimmings.

PI 2.2.6 - PRETANNING USING ALDEHYDES, PRODUCING CHROMIUM-FREE LEATHER

Description

The aim of this technique is to carry out the pretanning with aldehydes, followed by more intensive retanning.

The development of wet white pretanning systems was undertaken to address environmental matters, in particular the reduction of chromium in effluent and solid waste. These systems have become more and more used for the production of chromium-free leather for specific applications. The largest user of chromium-free leather is the car industry which requires high-performance leather. There are several processes possible for manufacturing wet white pretanned stock. Some aldehydes can be used as tanning agents and are widely used as pretanning agents for the production of chromium-free leather. Formaldehyde is no longer used in Europe for reasons of workplace safety. Glutaraldehyde, or more usually, glutaraldehyde derivates, are widely used for pretanning. Pretanning with aldehydes can be seen as a stabilisation of the leather and has to be supplemented by additional tanning.

Achieved environmental benefits

Reduction of the chromium emissions to the effluents (no chromium discharge) and less solid waste containing chromium. Glutaraldehyde is a widely used chemical. Extensive measures have been taken to monitor any negative effect in the urban sewage treatment plant, and no negative effects have been noticed. Oxazolidine may be used but detailed data about the environmental impact of this substance are not available yet.

PI 2.2.7 - PRETANNING FOLLOWED BY VEGETABLE TANNING WITH HIGH UPTAKE OF TANNING AGENTS

Description

This technique deals with the use of pretanning agents to aid tannin penetration and of short floats in drum tanning.

Systems with a high degree of tanning exhaustion (~95%) are available commercially. These systems have in common a pretanning step, e.g. with polyphosphates and/or syntans. Syntans are synthetic tannins and, generally, these are prepared as salts of polyphenolic sulphonic acids, from different simple phenols or from natural phenolic compounds (as lignosulphonates) by sulphonation and condensation. The addition of syntans will make the vegetable tannins penetrate the hides quicker and hence reduce the tanning time.

Drum tanning can be carried out using very short floats; this system allows the vegetable tanning agents to penetrate the leathers more quickly, reducing the overall tanning times. Drum processes for sole leathers are designed to be closed systems, so that very little waste liquor is discharged.

The leather is pickled and pretanned using sulphuric acid and polyphosphates. It is then moved into colouring pits and finally into tanning pits. The duration of the process varies from 7 to 21 days, and the discharge of tanning liquors is minimal.

Achieved environmental benefits

Reduction in the COD and BOD of the effluent compared to vegetable tanning with a lower rate of uptake of vegetable tannins.

PI 3 - POST-TANNING OPERATIONS

PI 3.1 - PROCESS CHANGES TO REDUCE METAL DISCHARGES

Description

This technique describes the use of high-exhaustion tanning, or ageing of chrome tanned leather to reduce leaching of the chromium during post-tanning.

Using a conventional technique, the amount of chromium in the waste water, deriving from the post-tanning operations, is approximately 1 kg per tonne of raw hide arising as shown in the table below.

Source of chromium discharge	kg chromium per tonne of raw hide
Leaching	0.6
In fine leather fibres	0.4
In metal complex dyes	0.03

Table 10: Sources for chromium discharge during post-tanning operations

A reduction of the leaching of chromium during the post-tanning processes can be obtained either using high-exhaustion chrome-tanning systems or allowing the necessary time for the tanned leather to ‘age’ prior to the post-tanning processes.

A very important factor for obtaining a high degree of fixation of dyes and fatliquors is to end the operations at a relatively low pH (the pH could be brought down to approximately 3.5). However, lowering the pH below 4 is, at the same time, an important factor causing chromium to leach out from the leather.

Another source for chromium discharge from post-tanning operations is that fine fibres from the shaving operation adhere to the leather surface and end up in washing and neutralisation floats. The chrome leather fibres may be eliminated by screening, e.g. with a wedge wire screen. The screening may take place at the site or as a first treatment step when floats containing chromium from the post-tanning operations are treated.

In metal complex dyestuffs for leather, the coordinating metal atom is iron, chromium, copper or cobalt. The metal complex dyes form a stable bond with the leather and the metal is an integrated part of the dye molecule. The maximum contribution of chromium from this source if the leather is dyed properly is 0.3% chromium in the leather and 0.03–0.05 kg chromium per tonne of raw hide in the waste water. The slight increase in the metal content can be avoided if acid dyes without metals are used (provided that the same final properties, in particular with respect to light fastness, can be obtained).

Achieved environmental benefits

The quantity of metals (in particular chromium) in the waste water will be reduced.

PI 3.2 - OPTIMISED RETANNING

Description

This technique pursues the optimisation of process parameters to ensure the maximum uptake of retanning chemicals.

Retanning agents are a major source of COD from the post-tanning operations. Apart from that, water and energy consumption are important parameters for the choice of a retanning process.

Processing parameters, e.g. the levels of chemical inputs, the reaction time, the pH and the temperatures, must be optimised during post-tanning processing to minimise chemical wastage and environmental pollution.

Achieved environmental benefits

Reduced discharge of retanning agents to the waste water.

PI 3.3 - OPTIMISED DYEING

Description

This technique is focused on the optimisation of process parameters to ensure the maximum uptake of dyes.

It is very desirable that the exhaustion of dyes is as high as possible and that the dyes are firmly bound to the leather. Dyeing auxiliaries such as amphoteric polymers may be applied in order to enhance the build-up of dye intensity. Furthermore, the degree of fixation of dyes is increased by processing at higher temperatures (60 °C) and a short float (100%). Finally, a very important factor for obtaining a high degree of fixation of dyes is to end the operation at a relatively low pH value (pH is typically brought down to about 3.5).

Achieved environmental benefits

Chemicals applied in the dyeing process that have not been retained by the leather are released to the waste water. They contribute to the COD and in some cases to the AOX. They colour the effluents or have to be assessed as single substances due to their high potential impact.

A high exhaustion of dyes prevents the waste water from being discoloured, indicating that the concentration of dyes in the waste water released from tanneries is below 10 ppm (as dye levels of 10 ppm or higher in waste water are visible to the eye).

PI 3.4 - OPTIMISED FATLIQUORING

Description

This technique aims to optimise the process parameters to ensure the maximum uptake of fatliquors.

Fatliquors can be a significant cause of waste water contamination, especially in the production of soft leathers, which require large amounts of fatliquor. Improvements can be achieved by higher exhaustion, thus reducing the COD levels in the waste water. The addition of amphoteric polymers improves the exhaustion of fatliquors.

Achieved environmental benefits

The COD in the waste water from the post-tanning operations may be reduced significantly. An exhaustion of fatliquor equivalent to 90% of the original offer can be considered achievable.

PI 3.5 - SUBSTITUTION OF NITROGENOUS COMPOUNDS IN POST-TANNING

Description

Nitrogen compounds are used at two stages of the post-tanning operations. Amino resins (urea-formaldehyde or melamine formaldehyde resins) are used in the retanning to give the leather fullness, and ammonia may be used as a 'penetrator' for dyes.

The amino resins can be substituted by other filling agents and ammonia can be substituted as a penetrator. Shoe leather tanneries have seldom used ammonia as a dye penetrator, as the alkaline pH can cause the grain to loosen. Producers of chromium-tanned upholstery leather used to use ammonia, but with the discussions of hexavalent chromium in leather and the possibility of ammonia causing the formation of traces of hexavalent chromium in leather, many tanneries have now changed to other dye-penetrating agents.

Many tanneries in Europe are producing large amounts of chromium-free leathers for the automotive industry and there is no need to use ammonia to penetrate the dye. The chromium-free leather is so anionic that the anionic dyes penetrate without the use of any other chemical.

Alternatively the penetration of the dyestuff through the substrate can be aided by thorough neutralisation using neutralising syntans, natural or synthetic anionic retanning agents prior to dyeing, a short and cold dyeing bath, better pH control of the leather cross-section prior to dyeing and, if necessary, by increasing the penetration time.

The use of the following salts in the neutralisation step is considered an achievable technique:

- Sodium bicarbonate
- Sodium formate
- Sodium acetate
- Borax
- Neutralising syntans

The input of the neutralising salts should be optimised to ensure that the pH of the liquor and the leathers by the end of the process are close to each other, ensuring that either no, or very little, unused salt is discharged to waste water.

The use of ammonia, ammonium salts, and salt-releasing sulphur dioxide (sodium bisulphite, sodium sulphite, sodium thiosulphate) is considered less environmentally friendly, although for the production of certain types of leathers the use of such chemicals is necessary.

Achieved environmental benefits

The contributions to the nitrogen load of the waste water is 0.2 kg organic bound nitrogen per tonne of raw hide from the amino resins and approximately 1 kg ammonia nitrogen (0.6–1.6 kg) per tonne of raw hide from the dyes, respectively. These discharges of nitrogen can be avoided if the proposed techniques are used.

PI 3.6 - USE OF LIQUID AND LOW-DUST DYES

Description

Within this technique, liquid dyes and de-dusted powdered dyes are used to achieve a reduction or the elimination of suspended particulate matter in the air exhausted from dye-handling areas.

Liquid dyes and dyes generating low levels of particulate matter were developed to prevent health impacts by dust emissions on the workforce while handling the products. Practically all powder dyes have been de-dusted for many years. Dye suppliers normally test every batch and comply with dusting specifications using standard test methods. A small amount of an anti-dusting agent, such as paraffin oil (typically < 1%) is mixed in with the dye powder shortly before packing.

For substances that are insoluble or hardly soluble in water, auxiliary agents are added. In the case of liquid dyes, this means using auxiliary chemicals to help either their solution or their dispersion in water. In choosing the auxiliaries, care has to be taken particularly with regard to cross-media effects on the waste water.

Liquid dyes are generally made up of the following materials:

- water and dyestuff
- diluents/fillers (chalk, syntans, polymers, etc.)
- surfactants (mainly used to aid the dispersion of non-water-soluble dyes)
- anti-foam (usually added in conjunction with a surfactant).

Information about the exact composition of a liquid dye is not generally given by the chemical manufacturer, which means it can be rather difficult to evaluate the environmental impact of the liquid dyestuff used.

Powdered dyes are now usually produced in de-dusted form.

Achieved environmental benefits

The main environmental benefit of the technique is a reduction or elimination of suspended particulate matter in the air exhausted from dye-handling areas.

PI 3.7 - DRYING

The processes used to dry leather have considerable effects on the properties of the final material. The choice of drying method is therefore always governed by the type being manufactured.

Forced drying of leather is among the most energy-intensive processes (apart from waste water treatment) in the tannery. Natural air drying does not consume energy but it is not applicable in all circumstances, as it requires time and favourable climatic conditions.

Other drying techniques are hang drying or suspension drying (cabinet or tunnel), vacuum drying, toggling (cabinet, tunnel or open air), paste drying, or radio frequency/microwave drying under vacuum.
Improved drying techniques are described in detail in PI 5.1.3 – IMPROVED DRYING TECHNIQUES.

PI 3.8 – METAL-FREE TANNING/DYEING

Recently there has been a great demand for metal-free automotive leather. For the production process of this leather, not only chromium, but all kinds of metal present in the retanning and dying agent should be avoided.

Usually for the excellent light fastness, metal complex dyestuffs are used. Due to the environmental impacts of metals present in dyestuffs, metal-free tanning/dyeing is recommended. *See BSP 3.9 – USE OF APPROVED DYES.*

PI 4 - COATING

PI 4.1 - CASTING/CURTAIN COATING

Description

The leather is fed through a curtain of liquid, which is deposited onto the leather surface. The technique is used for the application of heavy finish layers only.

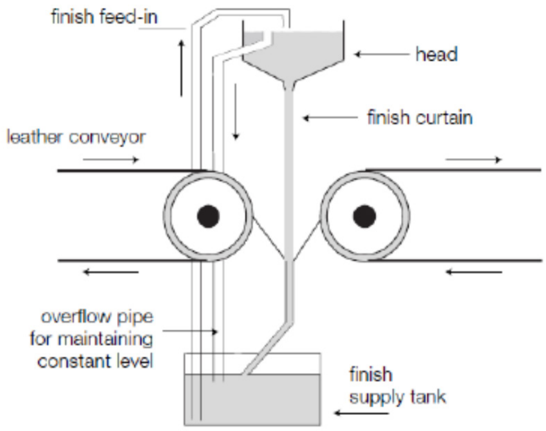


Figure 15: Operating principle of the curtain coater. Source: UNIDO and BASF

Achieved environmental benefits

Reduced amounts of waste and solvent emissions into the air are the main environmental benefits.

PI 4.2 - ROLLER COATING

Description

The finish is applied by grit rollers to the surface of the leather, similar to the process used in printing. There are differences concerning the grit size of the roller, the direction of application and the speed of the conveyor and the rollers.

This process is used especially, but not exclusively, to treat large pieces of leather, but the stability, softness and thickness of the leather are important parameters. The operation needs careful adjustment with respect to speed, viscosity and cleaning of rollers to produce the desired quality. It might not be applicable to very thin leathers.

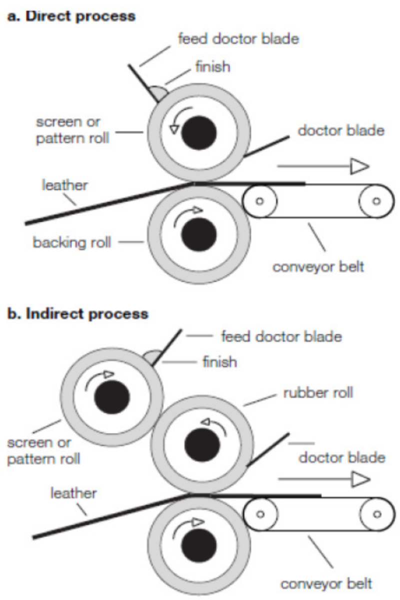


Figure 16: Operating principles of the roller coater. Source: UNIDO and BASF

Despite the fact that research and development are ongoing, roller coating techniques are considered to be general practice, as many tanneries use them. More specialist models allowing for hot and cold applications of oils, waxes and microfoam products are also available on the market and are used in several tanneries in Europe.

The same conveyor/drying unit as for the spraying booth can be used.

Achieved environmental benefits

The more efficient application of coating materials leads to less waste and less solvent emission for the coating of a given area, to the benefit of the environment. The avoidance of mist and solid particulate emissions associated with spraying is also beneficial.

PI 4.3 - IMPROVED TECHNIQUES FOR SPRAY COATING

Description

Spraying techniques with higher efficiency of coating transfer.

- High-volume low-pressure (HVLP) spray guns

This equipment sprays with a large volume of air at low pressure. Therefore the 'bounce-back' is considerably reduced compared with conventional spraying. The HVLP technique does not give completely satisfactory results for some articles, such as upper leather and garment leather and can be used mainly for upholstery leather.

- Airless spray guns

The coating material itself is pressurised. It is then atomised with a spray nozzle without the use of air. Airless spraying is more suited for high application rates.

- Computer-aided spraying

Computer-aided spraying means that automated systems sense the area, either by a mechanical feeler, electric eye or ultrasonic system and control the opening of the guns so that they only spray when the leather is passing directly beneath them. The technique is widely available in more or less sophisticated versions. Care must be taken that the detection equipment is properly adjusted.

Figure 17: Finished leather

Achieved environmental benefits

HVLP and airless spraying improve spraying efficiency up to 75%, compared to spraying efficiency as low as 30% for conventional spraying operations.

Computer-aided spraying can prevent 75% of the finish being lost as overspray. The emissions of spray mists are reduced, and because coating efficiency is improved, solvent emissions are reduced too.

PI 4.4 - WATER-BASED FINISHING

Description

This process improvement describes the use of finishing products which are dispersed in water rather than in solvent.

In the finishing process, water-based systems are increasingly favoured because of environmental concerns about organic solvents and in order to comply with regulations. For applying the coating layers, different techniques can be used *(see PI 4.1 - CASTING/CURTAIN COATING, PI 4.2 - ROLLER COATING and PI 4.3 - IMPROVED TECHNIQUES FOR SPRAY COATING).*

Organic solvent-based processes in closed spray cabinets and closed drying systems, which offer an acceptable environmental performance, require cost-intensive abatement techniques *(see PI 5.3 - AIR EMISSIONS ABATEMENT).*

In order to achieve equal characteristics with low organic solvent and water-based systems, cross-linking agents for the finishing polymers often have to be used. The toxicity of these agents is problematic, but commercial products offer the agents in a less toxic and less volatile form. Nevertheless, appropriate safety precautions are required when handling and applying these agents.

Organic solvents either are added in the formulation of the finish or are already incorporated in the finishing chemicals (i.e. lacquers) by the supplier. Many of the finishing chemicals do not specify the composition of the finish in terms of the type and quantity of organic solvent used.

The safety data sheets are generally the only source of information for the tanner.

For any organic solvent applied in the process that cannot be substituted by aqueous systems, the alternative is to use organic solvents with the lowest impact on workplace safety and the environment and, in order to make recycling feasible, to avoid mixtures.

The main parameters for an assessment of organic solvent-based finishing agents are:

- The type of organic solvent used with regard to toxicity and the recycling options;
- The efficiency of abatement in all processes where organic solvents can be released consequently, i.E. Also in drying and storage;
- The ratio of recycling or reuse of the organic solvent.

The minimum requirement for organic solvent-based coatings is the recording of solvent consumption, to include not only the solvents bought as solvents, but also the solvents contained in the finishing chemicals. This is the only acceptable way to calculate the overall emissions of VOC, because it is not possible in practice to monitor fugitive emissions. VOC releases from leather during storage are estimated as 10% of the applied organic solvents that remain in the leather and about 60% of the amount emitted in the drying tunnel. The rest is emitted during storage.

Achieved environmental benefits

The main advantage of water-soluble lacquers is the considerable reduction of organic solvent consumption and releases. Most water-based finishing products still contain a low amount of organic solvents.

PI 4.5 – BINDERS WITH LOW CONTENT OF FREE MONOMER AS FINISHING AGENT

In leather finishing various types of binders are used and many of them are polymeric emulsions. Polymer is produced by the polymerisation of monomers, so the presence of unpolymerised monomer is not desirable in the polymeric emulsion. In this case the monomer has impurities and sometimes is harmful for the environment. So the monomer content in polymeric emulsion of binder should be as low as possible.

PI 4.6 – HAND PADDING / ROLLER COATING

For leather finishing the use of the hand padding or roller coating system is better than the spraying method, from an environmental perspective. The spraying method pollutes the surrounding environment more than hand padding or roller coating. By doing hand padding / roller coating there is little chance of air emissions of chemicals. Usually impregnation is done by hand padding as more chemicals are absorbed by the leather compared to spraying.

Currently hand padding / roller coating is a more efficient application because this method of finishing leads to less waste and less solvent emissions.

PI 5 – OTHERS

PI 5.1 - ENERGY

PI 5.1.1 – USE OF SHORT FLOATS

Description

The use of short floats is described in BSP 4.1 - PROCESS WATER MANAGEMENT.

The use of short floats entails the starting and rotation of less-balanced process vessels. There is an increase in the rate of use of electrical energy, but this is balanced by the shorter process times involved.

Achieved environmental benefits

Because it reduces process water heating, the use of short floats can make an obvious difference to the energy use in a tannery.

PI 5.1.2 – ENERGY RECOVERY FROM PROCESS FLUIDS

Description

This section refers to the techniques to recover energy from process fluids.

Energy savings can be achieved by heat pumps incorporating recovery systems. Waste heat can be used from and for other processes.

By means of heat exchangers, energy can be recovered from the waste process water, from condensate from vacuum dryers, from evaporated water from high-frequency drying, or from exhaust air from drying.

The cooling water from the vacuum dryer, which is not polluted, can be used in the hot water supply.

Achieved environmental benefits

Reduced energy use may be achieved.

PI 5.1.3 – IMPROVED DRYING TECHNIQUES

Description

This process improvement pursues the improvement of drying techniques to reduce energy use.

Low-temperature drying (LTD) machines are available with reduced energy consumption, although in some cases they can lengthen the drying process (e.g. LTD drying tunnels may require all night to dry leathers, compared with 4 hours in conventional hang drying tunnels, but may have three times the capacity).

Considerable reductions in energy consumption can be achieved by optimising the mechanical dewatering processes prior to drying.

Temperature and humidity during drying need to be carefully controlled. Elimination of the greatest possible amount of water in samming may mean energy savings of 0.5–1 GJ/t of raw hide in drying. Keeping drying temperature low and drying time and amount of exhaust air at the necessary minimum will keep heat losses to a minimum (although the consideration of leather properties will have priority).

In order to avoid energy losses for reheating, drying installations should be run as continuously as possible. The heat capacity and heat transmission of new installations are as low as possible.

A system for the use of heat pumps in drying exists, developed in France *(see PI 5.1.2 – ENERGY RECOVERY FROM PROCESS FLUIDS)*. Without the use of a heat pump, the energy consumed is mainly thermal energy. The only exception is high-frequency drying, which uses electrical energy exclusively. Due to the high costs of electrical energy and to the high investment cost, this method has only gained limited acceptance.

It is obvious that natural drying of leather is the method with the lowest energy consumption, but it is impractical for much of the year in many parts of Europe due to weather conditions. These include low temperatures, high rainfall and the associated humidity, combined with unpredictable variations in all these factors.

For finish drying, infrared heating is an energy-saving method.

Achieved environmental benefits

Reduced energy use may be achieved.

PI 5.1.4 – ENERGY RECOVERY FROM WASTE BY DIGESTION

Description

This technique is related to the anaerobic digestion of organic waste fractions to produce a fuel gas.

Anaerobic treatment of waste is a well-known technique which can be used to produce energy from waste and by-products from the leather industry. Green fleshings are suitable for biogas production, but are subject to appropriate animal health controls.

Achieved environmental benefits

A reduction in fossil fuel use, CO2 emissions and volumes of waste for disposal.

PI 5.1.5 – ENERGY RECOVERY FROM WASTE BY COMBUSTION

Description

In this technique fat recovered from waste is burnt as a fuel.

Fleshings (and other fatty waste) are minced to approximately 5–10 mm, heated up to 75–85 °C and separated, e.g. using tricanters, into tallow (10–20%), solids 'greaves' (35–55%), and a water fraction (35–55%). The tallow contains up to 99% fat and can be used in an appropriate burner as a direct substitute for oil fuel. The calorific value is about 85–90%.

Achieved environmental benefits

A reduction of fossil fuel use and a reduction of the volumes of waste for disposal can be achieved.

PI 5.2 - WASTE WATER TREATMENT

PI 5.2.1 - MECHANICAL TREATMENT

Description

This treatment is focused on the screening of gross solids; skimming of fats, oils and greases; and removal of solids by sedimentation.

Mechanical treatment includes operations for a first treatment of the raw effluent. The solid and organic content in the untreated waste water and subsequently the loads introduced in the biological stage can be reduced through primary sludge separation.

Pretreatment includes screening to remove coarse material, for example pieces of skin and leather fibres, which would otherwise block pipes and pumps. Such screens need regular, preferably automatic cleaning and maintenance. The material removed is more concentrated and easier to handle. Mechanical treatment may also include skimming of fats, greases and oils, and gravity settling (sedimentation).

Achieved environmental benefits

Up to 30–40% of gross suspended solids (including hair and gross fats which are not in emulsion) in the raw waste stream can be removed by properly designed screens.

A preliminary settling operation for the raw waste water can remove up to 30% COD, thus saving flocculating chemicals and reducing the overall quantity of sludge generated.

PI 5.2.2 - PHYSICO-CHEMICAL TREATMENT

Description

Physico-chemical treatment involves sulphide oxidation from beamhouse effluents, chromium precipitation, flow equalisation, physico-chemical treatment for COD removal and balancing. A typical scheme for physico-chemical treatment is given in the figure below. Where chromium recovery is used, it is usual to treat chromium-bearing effluents separately from beamhouse effluents.

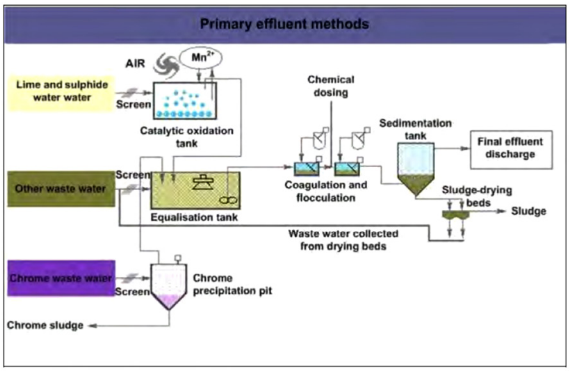


Figure 18: Typical scheme for physico-chemical treatment

Sulphide removal

The prevention of gaseous hydrogen sulphide releases is described in *PI 1.3.3 - PREVENTION OF H2S EMISSIONS FROM EFFLUENTS.* Sulphide removal from effluent can be achieved by catalytic oxidation (aeration in the presence of manganese salts) to thiosulphates and, in smaller quantities, into sulphates. The thiosulphate then decomposes into sulphur and sulphite with which it forms a balance. Hydrogen peroxide is expensive and when it is used, it is mostly in combination with aeration in the presence of manganese salts or iron(II) salts to avoid odour production.

Sulphides in effluents can also be removed by means of precipitation with iron(II) salts and aeration. Due to the aeration, iron(III) hydroxide and sulphur are formed; the black sludge turns brown and settles easily. Together with the iron(III) hydroxide, the bulk of the organic substances will settle. Iron salts can be used when treating either mixed tannery effluents, or separated waste water streams. This precipitation generates very high volumes of sludge, and if the sedimentation is not sufficient the iron salts give a brown colour to the effluents. The most common system for tanneries is the use of catalytic oxidation using manganese sulphate as a catalyst.

Sulphide oxidation in the drum can be complete, but it may need to be carried out in combination with sulphide oxidation of the effluent in a designated treatment facility.

Aeration can eliminate the problems with sulphides and it can be achieved by blowing air at the base of a tall tower, through a set of diffusers. The manganese salts may be added manually for a batch process. Continuous sulphide oxidation systems are available with full automatic control.

Foaming can be reduced using auxiliary agents, or by a limited application of kerosene.

The catalytic oxidation does not irreversibly turn the sulphides into sulphates; in fact, the reaction creates reversible compounds which are able over time to revert to sulphides (e.g. during storage in a homogenisation tank without sufficient mixing). For this reason, the treatment is not deemed suitable for lagoons. If catalytic oxidation of sulphides is carried out, there is a chance that compounds containing amines can be stripped from the effluent, resulting in odour emissions. Biological oxidation of sulphides in effluent is also possible during biological treatment of the effluent.

If the effluent containing sulphide is mixed with effluents from vegetable tanning, sulphide oxidation is possible just using good aeration; alternatively, aluminium salts can be used because iron salts form black compounds with the vegetable tannins.

Precipitation of chromium

Chromium(III) precipitation is a relatively simple technique and is more efficient if it is carried out in separated effluents after screening. The precipitation of chromium is achieved by increasing the pH to above 8 using an alkali such as calcium hydroxide, magnesium oxide, sodium carbonate, sodium hydroxide and sodium aluminate. Chromium and other metals are precipitated as insoluble hydroxides. The pH value required for the precipitation depends upon the type of waste water containing chromium to be treated. Where chromium(III) precipitation is used it is common practice to segregate the effluent streams which contain chromium from those which do not and carry out chromium precipitation on segregated flows before effluent mixing. Where segregation of flows is not possible or where chromium recovery is not used, mixing in contained conditions can be used so that some or all of the alkalinity used to precipitate the chromium is provided by lime in the beamhouse effluent. Chromium recovery is discussed in *PI 2.2.4 - CHROMIUM RECOVERY THROUGH PRECIPITATION AND SEPARATION.*

The precipitation can be inhibited or reduced to an unsatisfactory level by the influence of residual organic matter, masking agents, other complexing agents, fats or dyestuffs in the waste water.

Suspended solids (leather fibres, etc.) must also be considered, as chromium salts are adsorbed to the surface of the particles and colloids, thereby inhibiting precipitation to the extent that emission limit values are not met. An additional filter for filterable solids might be necessary before discharging.

Flow equalisation

Flow balancing and the combining of effluents are necessary to deal with peak flows. Balancing may be carried out after individual effluent flows have been pretreated, such as sulphide oxidation and chromium precipitation.

The effluents from various process steps vary in composition and are generated at different times during the day. In order to even out the variations in composition in effluents and achieve an efficient balancing of the effluents, the balancing tanks need to be able to hold at least one day's effluent.

Combining effluents can often lead to co-precipitation of pollutants, thus improving the efficiency of COD removal. It is essential that mixtures be well mixed, that suspended solids do not settle and aerobic conditions are maintained. Mechanical stirring devices or an air injection system have to be installed. Air injection also encourages flocculation.

COD removal

A substantial percentage of the COD and suspended solids can be removed after coagulation and flocculation. In order to optimise the removal, the pH of the effluent needs to be controlled to the level where coagulation and flocculation agents are most effective.

After setting the pH value and following the necessary settling period, a coagulant such as aluminium sulphate, ferrous sulphate or polymer flocculating agents can be added to the waste water. This creates a flocculate, which settles well and consists of the precipitation chemicals and organic and inorganic residual contents in the waste water, depending upon the pretreatment applied. If no chromium precipitation has been carried out at an earlier stage, chromium hydroxide will be formed at this stage and removed in the primary sludge. Ferrous sulphate also removes sulphides, but the disadvantages have to be taken into account. Polymer flocculating enhances the efficiency of the flocculation, but also increases the volume of sludge considerably. The optimum dosage and conditions are usually established by on-site experiments.

Flotation is a method for removing suspended solids and other matter from a mixed effluent. It works on the reverse principle to sedimentation, employing fine air or gas bubbles to lift the suspended solids to the surface from where they may be removed.

A commonly employed system is dissolved air flotation. Air is dissolved under pressure in a saturator with part of the treated effluent. When the pressure is subsequently lowered in the treatment vessel, small air bubbles are formed. These bubbles rise and carry the suspended solids to the surface. A scraping device periodically removes the surface 'blanket'.

The flotation process relies on coagulant and flocculant chemical conditioning of the feed stream, as in sedimentation, in order to enhance the separation process of the solids. The effluent feed may require pH adjustment, followed by dosing of a suitable coagulant. A suitable polyelectrolyte flocculant may also be required for optimum phase separation, especially of colloidal solids, and will require dosing just prior to the effluent entering the flotation tank.

Membrane processing

Raw or wet blue skins are transformed into clothes, shoes and other leather goods using diverse chemicals such as acids, alkalis, chromium, salts, tannins and sulphides. Membrane processes offer the possibility to remove the salts as well as organic material using a chemical-physical process. The previous separation of reusable and non-reusable substances facilitates the recycling process and enables a more efficient treatment of the produced sludge which can be used as fertiliser in agriculture.

Ultrafiltration (UF)

Ultrafiltration (UF) represents a good preliminary treatment method to remove particles which are larger than 200 to 300 nm in size. 90% of the solids will be retained while the suspension passes through a filter membrane. Using UF systems, fluid streams can be released from suspended particles. The produced filter cake further supports the removal of organic material as it accumulates in the sludge. The salt-containing permeate could be reused in the pickling and liming step. This method results in lower costs and a reduction of the environmental impact in regard to the ability of recycling the waste water and avoiding a step in waste water treatment.

Each kilogram of treated leather requires an input of 0.012 kg of sulphides. 20% of the sulphide is used for the unhairing process and attached to the leather. Hence, the outcoming fluid stream contains about 60% of sulphides. The efficiency of the UF membrane to recover the sulphides is 55 to 60% whereas 70% of the water can be recycled. Hence, the environmental impact is reduced as the excess liming agent that is retained by the UF membrane can be returned into the process cycle after adjusting the salt concentration. In addition, the raw material input is reduced and the waste water plants benefit from less-contaminated waste water.

The filter material is of great importance as it influences the substances in the fluid stream. Tubular membranes that are made of carbon fibres retain up to 60 to 85% of proteic substances whereas non-cellulosic membranes and flat sheet membranes eliminate sulphides by 2%, and more than 85% of proteic and colloidal substances is obtained.

Regarding the elimination of sulphides, 5 to 10% of the initial sulphide amount is retained by the filter cake whereas 60 to 65% is still present in the permeate after passing through the membrane filter. As a result, 55 to 60% of the sulphide can be recycled using the UF method. In the degreasing step, it was demonstrated that the initial fat content in pickled skin could be reduced by 55%. A traditional dry degreasing process with tetrachloroethylene shows a similar elimination rate. Hence, UF systems are comparable in efficiency to commonly used processes. In addition, the loss of water supply is minimised in repeated washing steps to remove the fat from the degreasing fluid stream.

Microfiltration and centrifugation

Microfiltration and centrifugation exhibit other preliminary process techniques to eliminate larger particles from the waste water. In a recent study, an effective way of unhairing using an enzyme resulted in a sulphide reduction from 10% to 1.5% in terms of dry skin compared to the traditional process. In comparison to the former process, the hair remains in its initial state preventing the formation of hazardous by-products. Using these new innovation techniques, pollution caused by sulphide-containing waste water is reduced and hence, this results in environmental protection as well as in safer work conditions for employees. However, as this result is based on a pilot industrial scale, tanners have to adjust their own procedure by testing and evaluating.

Nanofiltration (NF)

The recovery of the chromium amount in the outlet stream after the tanning process step requires an efficient process. Experimental tests illustrated that nanofiltration (NF) is an effective method (99.9%) in regard to the removal of chromium. Table 11 shows a material balance of the NF process for some substances:

	Initial float	Average filtrate		Final retentate	(%)	Balance (%)
Volume	178l	123l	69%	55l	31	100
Chromium	486g	3.7g	1%	511g	105	106
TSS	27g	3.4g	12.6%	20g	74.1	86.7
COD	912g	408g	45%	420g	46	91
Chloride	1930g	1622g	84%	406g	21	105
Sulphate	4983g	597g	12%	4590g	92	104

Table 11: Material balance of the NF process

In addition, the retained chromium can be returned to the process after additional concentration. The recovered chromium has been observed to be of similar effectiveness in the process as using a fresh chromium solution. Furthermore, NF membranes can be applied in vegetable tanning to recycle the used tannins after adjusting the concentration. Tannins which are 300 to 800 Da in molecular weight aggregate and hence they can be separated from the salts. The permeate will be sent to a waste water cleaning plant.

Reverse osmosis

The pickling fluid stream features an osmotic pressure of 12 to 15 bar and hence enables the application of reverse osmosis. The salt is concentrated in the retentate and reused in the pickling process after adjusting the salt level. The permeate can be used as washing water or returned to the soaking step. As the recovery of dyeing substances is well established in the textile industry and as the chemical parameters are comparable to the dyeing step in leather manufacturing, reverse osmosis represents an efficient method to separate dyeing agents from the fluid stream.

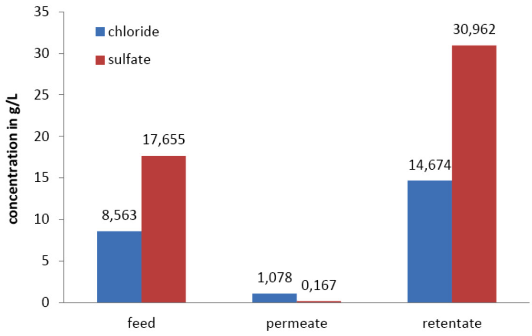


Figure 19: Chloride and sulphate concentration using reverse osmosis

Achieved environmental benefits

Achieved environmental benefits of the techniques are:

- A reduction of the concentration of substances in the waste water, particularly chromium and sulphides, and in chemical oxygen demand;
- Preparation of the waste water for biological treatment.

PI 5.2.3 - BIOLOGICAL TREATMENT

Description

Effluent from tanneries after mechanical and (usually) physico-chemical treatment is generally easily biodegradable in biological treatment plants. Tannery effluent may be treated with or without the addition of sewage from other sources. Small amounts of phosphate may need to be added to maintain the biological activity. Standard aerobic biological treatment plants are normally used; their size and abilities depend on the local situation, i.e. on-site or off-site treatment. Prolonged aeration time is important for tannery effluent treatment.

Sulphate-reducing bacteria flourish in anaerobic conditions. Precautions to prevent the release of hydrogen sulphide are necessary, either by exhaust gas treatment or by the removal of sulphur compounds prior to the anaerobic treatment.

Anaerobic treatment produces less sludge than aerobic treatment. For the anaerobic treatment of waste water effluents from beamhouse processes, a COD reduction of 40–62% is reported.

Biological treatment combined with physico-chemical treatment can achieve a COD removal of up to 95%. Biological treatment is now used without physico-chemical treatments in some effluent treatment plants, as a measure to reduce the total sludge output from the process.

Most biological treatment plants use the activated sludge (bio-aeration) method. This uses the metabolic activity of microorganisms in suspension. They convert the dissolved, biologically convertible contents into carbon dioxide and activated sludge. Other substances, such as metals, are adsorbed by the sludge.

Oxidation takes place in a continuously aerated tank. A retention time of 6–12 hours usually suffices. The energy consumption of a conventional activated sludge plant is about 1.08–1.8 MJ per kg of BOD5 eliminated.

A modified extended aeration/low load activated sludge system employs a longer retention time and thus yields greater protection against shock loading. It may need retention times of one to three days, with subsequent energy input greater than 3.6 MJ per kg of BOD5 eliminated.

Achieved environmental benefits

The technique can achieve a reduction of oxygen demand of the effluent, to a level where it can either be safely discharged to a water body or meet the specification of an organisation providing off-site treatment.

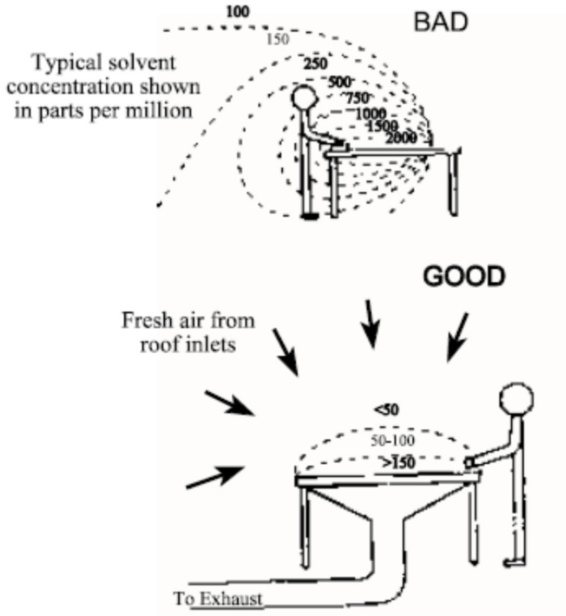


Figure 20: Ventilation of working areas

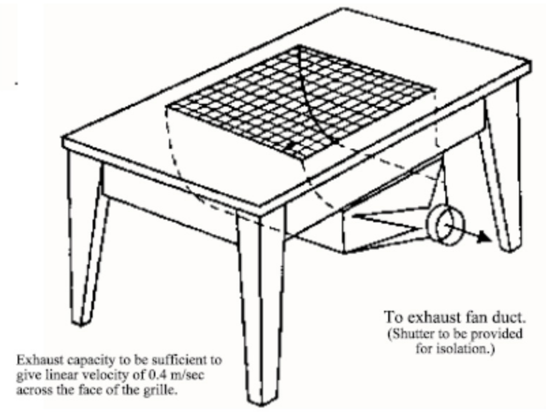


Figure 21: Work bench with grille in working surface

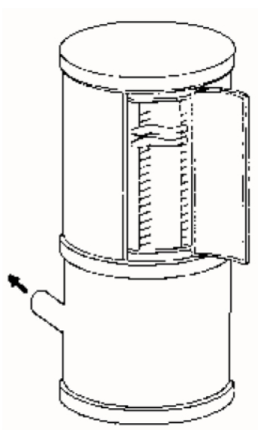


Figure 22: Extracted sole drying cabinet with rotating rack

PI 5.2.4 - POST-PURIFICATION TREATMENTS AND SLUDGE HANDLING

Description

For an overall assessment of the waste issue, both contributions to the generation of sludge have to be taken into account: first at the tannery and secondly at the (urban or off-site) waste water treatment plant. Precipitation in the tannery extracts not only heavy metals but also organic components that might cause a high COD.

In order to remove suspended solids, (vertical) sedimentation tanks or flotation are used. The separation of the activated sludge from the purified overflow is normally carried out by continuous sedimentation in a post-purification tank. Sludge from primary sedimentation may only contain 3–5% solids, and can be handled by pumping or gravity.

With sedimentation, the sludge is separated from the liquid phase by gravity settlement. It is essential to allow enough retention time to prevent too much turbulence and clogging. The segregation of solids might not be complete, resulting in the carry-over of suspended solids into the discharge effluent. As a result, it is possible that certain emission limit values will be breached.

Dewatering is often practised to reduce the volume of the sludge for disposal. Sludge can be dewatered by means of filter presses, belt presses, centrifuges and thermal treatment. In most cases, flocculation agents have to be added. Filter presses are capable of producing a sludge cake with up to 40% dry solids, whereas belt presses produce a sludge cake with up to 20–25% dry solids. Centrifuges are useful in attaining sludge with up to 25–45% dry solids.

Thermal treatment can produce sludge cake with up to 90% dry solids. Prior to dewatering, sludge thickeners can be employed to further thicken sludge.

Achieved environmental benefits

The main benefits for the environment from the use of the techniques are a reduction in suspended solids in the waste water and reduced water content in the sludge (which increases the range of possibilities for its disposal).

PI 5.2.5 - SEWERS ADAPTED FOR TANNERY EFFLUENTS

Description

Common effluent treatment plants are often used for collective treatment of tannery waste water. Sewers are used to reach the plant, but sometimes their characteristics are not adapted to the special requirements of typical tannery effluent.

The following recommendations are proposed to prevent any damage or accident that might happen when using inadequate or inappropriate equipment.

Hydrogen sulphide

Acidification of any sulphide containing liquors generates hydrogen sulphide. Therefore alkaline and acid floats should be kept separate in the tannery.

All sulphur compounds can generate hydrogen sulphide, mainly under anaerobic conditions. Tanneries processing raw hides/skins mainly use sodium sulphide to remove hair or wool. Tannery effluent may contain sodium sulphide and therefore it is highly dangerous for anybody to enter a sewer without proper monitoring and without respiratory safety equipment. Even with careful sulphide oxidation in the tannery, there is a risk of H2S being developed in the sewer under acidic conditions and this gas has severe effects on unprotected humans, depending on concentration and exposure time. It is recommended that mechanical systems are used to clean sewers.

Sulphide and other sulphur compounds are also a danger for concrete sewers, because they can be oxidised to sulphate, which solubilises the calcium content of cement and concrete and thereby damages the fabric of the sewer. It is recommended that tanneries should use plastic sewers or plastic lined sewers. PVC, polyethylene or fibre reinforced plastic sewers are suitable for transporting tannery effluent.

Solid deposit

Tannery effluent typically contains a large amount of suspended solids (1 to 3 g/l) and when the flow circulation is too slow, deposits can occur, so clogging is likely. It is recommended that smooth materials should be used for the sewer and to maintain a minimum slope of 1 cm per metre in length. Manholes should be installed at each angle of the sewer and the distance between two manholes should not exceed 50 metres.

In order to reduce clogging in the sewer, it is recommended that solid waste should be separated from effluent streams, by using a screening unit with holes or spaces between bars not larger than 10 mm. Some mechanical screening equipment with finer mesh (2 mm or less) can be used to reduce the quantity of hairs and fibres sent to the effluent treatment plant. Appropriate pretreatment is required if effluents are transferred to a common effluent treatment plant.

Achieved environmental benefits

Reduced volume of waste water produced.

PI 5.3 - AIR EMISSIONS ABATEMENT

PI 5.3.1 - ODOUR

Description

Odours can arise from the decomposition of incorrectly cured or stored hides, accumulated waste, beamhouse processes, and waste water treatment plants that are poorly controlled and maintained.

Odours are not necessarily harmful or toxic, but constitute a nuisance to affected neighbours, which in turn gives rise to complaints. Apart from a natural, distinct smell of raw hides, bacteria degrading the organic matter can cause putrefaction odours. It is in the interest of the tanner to prevent any damage to the hide (capital invested in the hides and skins is relatively high) from putrefaction. These odours from the raw hides can be readily avoided at source with proper storing and curing of raw hides and skins. The prevention of these odours from waste, beamhouse and waste water treatment requires correct control of these operations. Waste should be removed methodically before their decomposition causes problems.

Some toxic substances are also odorous, e.g. hydrogen sulphide, thiols, ammonia, amines, aldehydes, ketones, alcohols or organic acids. These releases may require abatement.

The following are some specific recommendations for the control of odours both inside and outside tanneries:

Air treatment

Tanneries should be well ventilated and the air from odorous areas should be exhausted and treated. Air treatment can be done biologically by blowing the odorous air through a moist biofilter bed (compost, peat, humus) rich in microorganisms. For effective elimination of the odour, retention time of about 20 seconds is recommended. These biofilters are now widely used and are very cost effective. Air can also be scrubbed using chemical treatments (acid, alkali and oxidant washing of the air), but running costs are higher. Areas requiring treatment include deliming drums and areas where VOCs such as glutaraldehyde and solvents are used.
Please see PI 5.3.3. AMMONIA AND HYDROGEN SULPHIDE.

Putrefaction

Care should be taken in the preservation and storage of wet salted hides/skins, particularly in hot weather. Cooling equipment can be used to maintain storage temperatures below 30°C. Putrefaction of untanned solid waste can be an important source of odour. Wet waste should only be kept in the factory for a very limited time and can be partially stabilised with lime or by cooling.

Hydrogen sulphide

The very toxic gas hydrogen sulphide (H2S) has the odour of rotten eggs and is released when sulphide-containing liquors or hides are acidified. This occurs in deliming and when alkaline effluent liquors mix with acidic streams. Concentrations of 200 ppm H2S for 1 min can cause loss of consciousness, 500 ppm causes a deep coma with convulsions and exposure for 1 min at 900 ppm causes death. The limits for exposure are 10 ppm for 8 hours or 15 ppm for 15 min. The odour threshold for H2S is 0.08-2 ppm. H2S is especially dangerous because at levels over 200 ppm the odour is no longer detectable by the human nose. Portable detection devices are therefore essential.

Deliming should be done in a closed vessel to reduce release of both H2S and ammonia. The addition of small quantities of oxidising compounds (such as hydrogen peroxide or sodium bisulphite) can reduce H2S release during deliming.

Effluent from unhairing and liming processes contains high concentrations of sulphide. These liquors should be oxidised, usually using manganese sulphate as a catalyst, before being mixed with acid effluent or being discharged to the general mixing tank, which generally has a pH of 8.5-9. Alkaline and acid floats should be kept separately in the tannery.
Please see PI 1.3.3 - PREVENTION OF H2S EMISSIONS FROM EFFLUENTS and PI 5.3.3 - AMMONIA AND HYDROGEN SULPHIDE.

Waste water and sludge treatment

Effluents are an important source of odour. H2S release occurs at different steps and care should be taken to limit its formation by maintaining the pH over 10 in the equalising tank and in the sulphide oxidation tank. H2S is also generated when sulphate containing liquors and sludges become anaerobic. Anaerobic conditions in tannery waste are odorous and dangerous. Low levels of manganese sulphate can help to avoid odours in treated effluent as it facilitates the oxidation of any sulphides present.

Tannery sludge storage in a thickener, or at a dry solid content below 30%, causes noxious odours. Sludges can be stabilised with lime to minimise odour problems. It is recommended that sludges are in the thickener for the minimum time and are quickly dewatered by centrifugation or filter press and dried. Biofilters can also be used to treat the air in areas where sludge is thickened and dewatered.
Please see PIs related to waste water treatment: PI 5.2.1 – MECHANICAL TREATMENT, PI 5.2.2 – PHYSICO-CHEMICAL TREATMENT, PI 5.2.3 – BIOLOGICAL TREATMENT and PI 5.2.4 – POST-PURIFICATION TREATMENTS AND SLUDGE HANDLING.

Volatile organic compounds

The VOCs in tanneries include solvents used in finishing, dry cleaning and degreasing, cross-linking agents, polymeric finishing agents and volatile tanning agents.

The finishing step is one of the main sources of VOCs, for example, butyl acetate, ethyl acetate, acetone, methyl isobutylketone and methyl ethyl ketone. They should be restricted to a minimum.

Most VOCs used in tanneries have a strong smell and many of them, including aqueous-based products such as formaldehyde, glutaraldehyde, etc. are toxic when present in the air at low concentrations (there is a safety limit of 0.6 mg/m3 for formaldehyde). All areas where VOCs may be present should be well ventilated and the air should be exhausted and treated appropriately.

Solvent degreasing is a source of odour. Care should be taken to control odours during float recovery, solvent distillation or skin storage.

Cleaning solvents can be used in various steps of the process, mainly for maintenance purposes. Storage of leather with finishes containing organic solvents can lead to occupational safety and health problems if ventilation is not adequate.

Generally most factories require some sort of extraction to keep the working environment safe. Care needs to be taken in the positioning (Figure 19) and specification of the extraction system so that it operates effectively. Typical examples of local exhaust ventilators include adhesive application benches (Figure 20), drying racks (Figure 21) and adhesive applying machines.
Please see PI 5.3.2 – ORGANIC SOLVENTS.PI 5.3.2 – ORGANIC SOLVENTS

Description

Because of the limited applicability and effects of air abatement techniques, the best option to reduce VOC emissions is the use of water-based systems and to optimise the application technique *(see PI 4.1 - CASTING/CURTAIN COATING, PI 4.2 - ROLLER COATING, PI 4.3 - IMPROVED TECHNIQUES FOR SPRAY COATING and PI 4.4 - WATER-BASED FINISHING).*

Abatement techniques are important for the protection of the environment, but they shift the pollution problem from air to water and waste. Recovery of organic solvents should take priority over any end-of-pipe solution. It should be noted that the recovery and reuse of organic solvents might only be feasible if a limited number of organic solvents are used.

There are various abatement techniques available to reduce VOC emissions:

- Wet scrubbing
- Adsorption
- Biofilter
- Incineration

Wet scrubbing is a standard technique for waste gas treatment, but is most effective against dust and aerosols. Water-soluble solvents dissolve in the scrubbing water. The increased use of water-dispersed finishing materials, mainly based on glycols or alcohols, has meant that wet scrubbing is now a more effective technique. Approximately 50% of the solvent releases can now be removed by wet scrubbing.

Adsorption techniques, e.g. with activated carbon, only work if the concentration/volume ratio is within a certain limit and remains relatively steady while the adsorption units are charged (desorption by less loaded off-gas streams). Adsorption with activated carbon is the standard technique for the abatement of halogenated hydrocarbons. Some organic solvents can be recovered by desorption from the adsorption material. After exhaustion of the recycling capacity the adsorption material has to be disposed of. For halogenated hydrocarbons, activated carbon filters are the only means of achieving the required abatement.

Biofilters can be used. Besides removing odours they can be used to oxidise soluble organic solvents such as alcohol, ketones, ester and ethers. For reliable operation, biofilters require careful control of the process parameters. They cannot be applied to off-gas streams where concentrations are high.

Incineration (catalytic or thermal) is a reliable but expensive method of abating organic solvent emissions and odours.

Achieved environmental benefits

Reduction of VOC emissions to the environment.

PI 5.3.3 - AMMONIA AND HYDROGEN SULPHIDE

Description

After all primary measures for ammonia and hydrogen sulphide reduction have been used these substances are usually removed by extraction ventilation systems. Unless the attenuation available between the release point and receptors can reduce the concentration to a level below that at which odour nuisance is likely, exhaust air treatment will be required.

Lower concentrations of these substances can be abated by biofilters, but at higher concentrations, they poison the microorganisms which carry out the treatment. At these concentrations, a wet scrubber may precede or replace the biofilter. Wet scrubbing of ammonia uses an acidic solution; and that of hydrogen sulphide uses an alkaline solution, such as hydrogen peroxide or a mixture of sodium hydroxide and sodium hypochlorite.

Achieved environmental benefits

Reduction of odour nuisance.

PI 5.3.4 - DUSTS AND OTHER PARTICULATES

Description

Airborne particulate matter can arise not only from mechanical operations such as milling, buffing and staking but also during handling of powdery process chemicals. Bating agents might use sawdust as a carrier. The parameters for assessing emissions of particulates are the concentration, the chemical content and the particle size.

Extraction of particle-laden air is undertaken for reasons of workplace safety. Filtration of the extracted air is necessary to protect the environment. With very efficient filtration, the air may be returned to the workplace.

For the most effective control of dust and to prevent fugitive emissions the considerations given below apply.

Dust should be controlled at source, e.g. one tannery uses soluble packaging for dusty process chemicals.

Operations and machines producing dust should be grouped in the same area to facilitate dust collection.

Dust collection systems are designed and built for the material and the situation. Fans need to be purpose-built and stress-relieved before dynamic balancing for low power consumption and noise levels. Ducts need to be designed for the desired suction pressure at the machine hood and smooth airflow. Due allowance should be made for the pressure drops of collection equipment.

Particulate matter collection techniques are presented in the following table:

Cyclones	Cyclones allow highly efficient collection of the larger particles and have relatively low capital and running costs. They can also be used in combination with bag filters and wet scrubbers.
Scrubbers	Scrubber systems can be venture scrubbers, spray scrubbers, packed static/mobile-bed scrubbers or cyclone scrubbers. The water can be recycled and the slurry has to be disposed of. Wet scrubbing is applied for particulates especially if soluble organic solvents and/or odours have to be removed at the same time.
Bag filters	Bag filters can provide an excellent solution. The choice of type and the area of the filter fabric are critical to the efficiency. Bag filters must have automatic cleaning devices (e.g. reverse air jets) to remove the caked dust from the filter fabric. Moisture has to be avoided in order to solidify the material on the filter matrix.

Table 12: Techniques for particulate matter collection

Achieved environmental benefits

The reduction of particulate matter emissions to the air.

7.2 MANUFACTURING

The figure below shows the main unit processes related to footwear manufacturing:

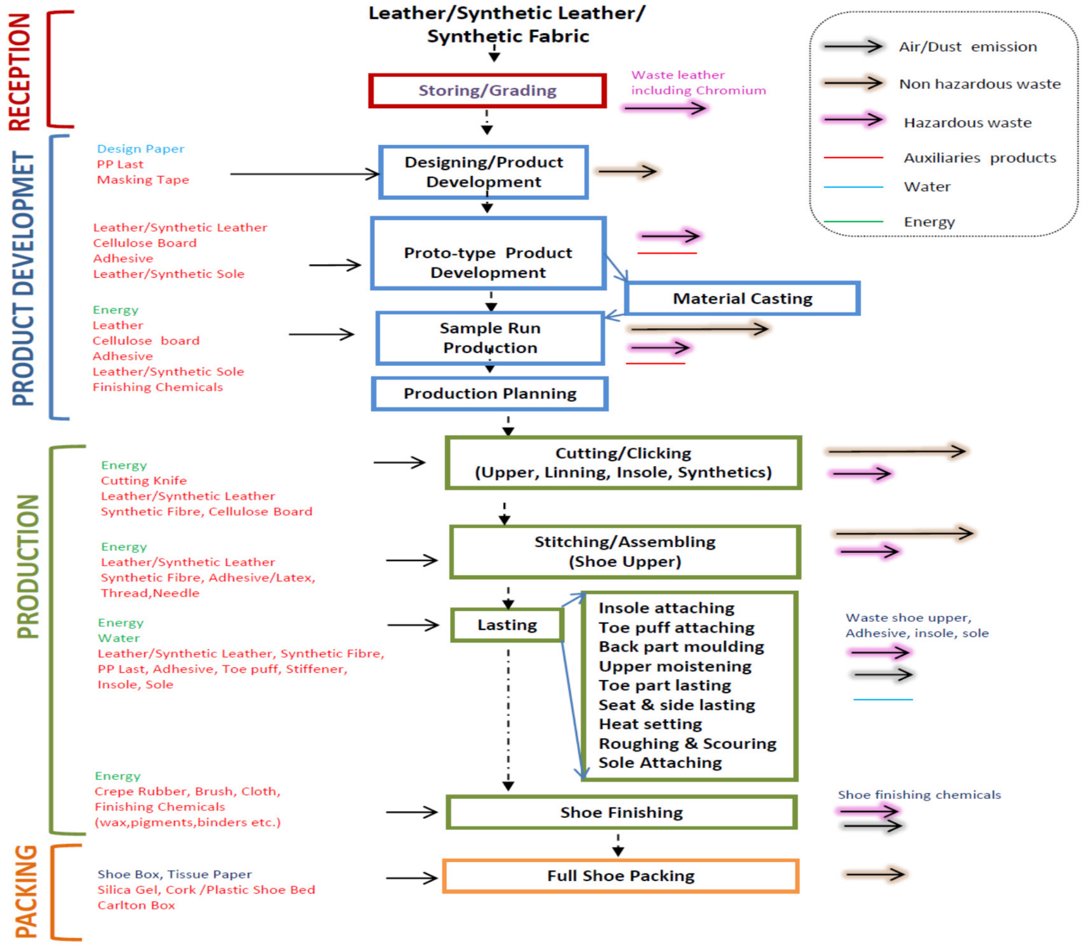


Figure 23: Footwear manufacturing flowchart

PI 6 DESIGN / PRODUCT DEVELOPMENT

PI 6.1 – ENVIRONMENTALLY FRIENDLY DESIGN

70-80% of a product's environmental impact is determined in the design stage. Waste minimisation strategies should start at the beginning of a product's life cycle, here in the product design phase using ecodesign improvements. Ecodesign improvements in the leather manufacturing sector could have a significant impact on environmental quality and could reduce the amount of materials needed, thus reducing the amount of waste that needs to be handled at the end of the life cycle.

Only a small part of global footwear/leather goods production has been estimated to be recycled or reused, with most being disposed of in landfill sites. One of the primary reasons for the low reuse/recycling rate is that most modern products contain a complex mixture of leather, rubber, textile, polymers and metal materials that makes it difficult to perform complete separation and reclamation of material streams in an economically sustainable manner. In addition, a product which is designed for ease of disassembly will make reuse and recycling of its components and parts easier, thus reducing the amount of materials disposed of into landfill.

The environmental properties of a product can be improved by simply choosing different materials. Material substitution is a proactive approach which can achieve significant reduction

The main steps carried out during the production process of leather goods are shown the figure below:

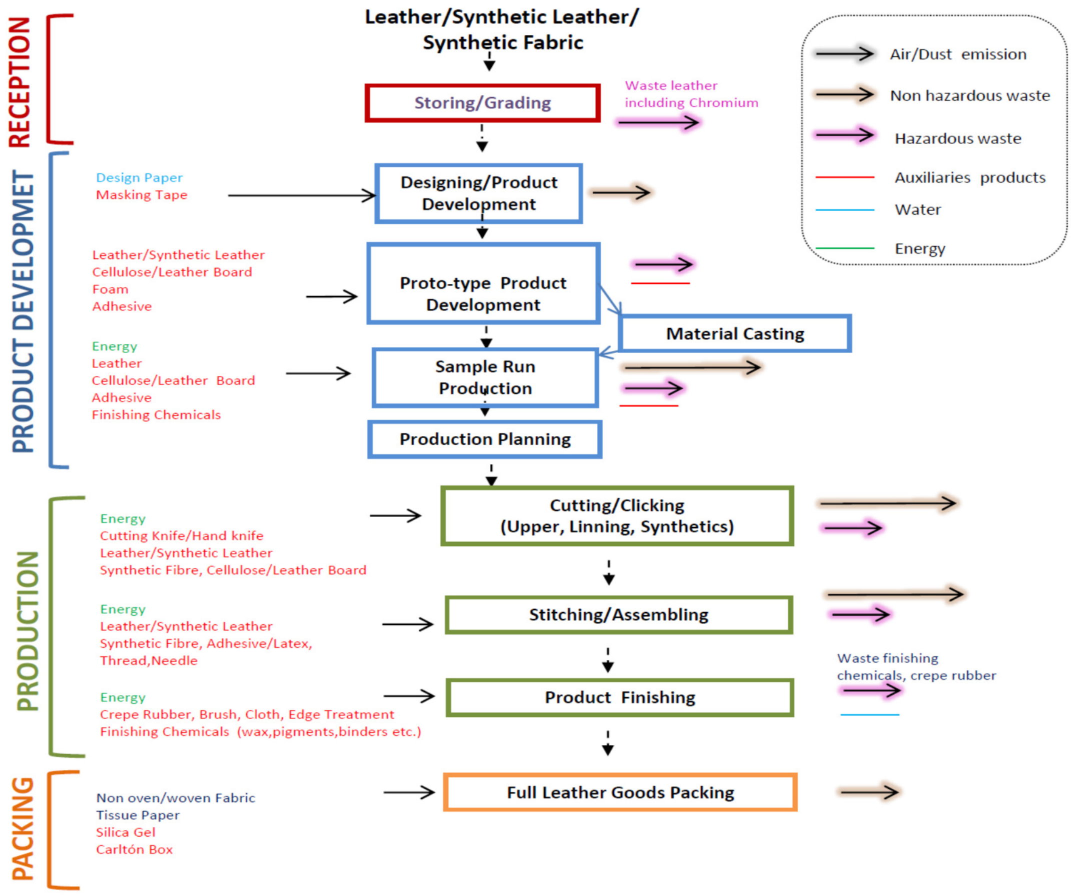


Figure 24: Leather goods manufacturing flowchart

of waste, under certain circumstances *(see BSP 6.6 – WASTE MANAGEMENT IN FOOTWEAR MANUFACTURING)*. Furthermore, biodegradable materials can substitute conventional materials in order to improve the environmental properties of the product. The two most important features that distinguish biodegradable materials from conventional petrochemical materials are their potential biodegradability or compostability at the EoL phase and the use of renewable resources in their manufacture.

In addition, other ecodesign measures are the following:

- Use of more sustainable raw materials.
- Select materials and design styles that will promote durability and longer use of the garment.
- Choosing particular fabrics that require less detergent and can be cleaned in cold water will have relatively reduced environmental impacts.
- Use of recycled materials.
- Use of seams instead of glue.

Eco Product

- Environmentally-preferable attributes of a product, service and/or technology;
- Any product which reduces impact on the environment and is 'Greener' in comparison with other products in the same category or with similar functionality (GPNM);
- Product and services that comply with environmental regulations or are environment-friendly, reflecting manufacturers' voluntary efforts to care for the environment;
- Green products might typically be formed or partly formed from recycled components, be manufactured in a more energy-conservative way or be supplied to the market with less packaging (or all three).

Understanding how the product is made, what it is made from and how it will be used and finally disposed of are essential. These attributes are compared with products that are similar or have the same functionality. If the product is better in one way in regard to its environmental impact at each stage of its life (material collection, production, transport, use and disposal), then it can be considered an Eco Product.

Product Life Cycle

The life cycle (LC) of a product refers to the stages that a product goes through in its entire existence. It covers:

- Aspects from its birth or cradle stage, where materials are extracted or gathered for the manufacturing of this product;
- Processing of its parts and assembly of the final product;
- The packaging and transportation stage from supplier to trader or other manufacturers;
- Use of the product in any sense and attribute;
- Its disposal stage or grave stage.

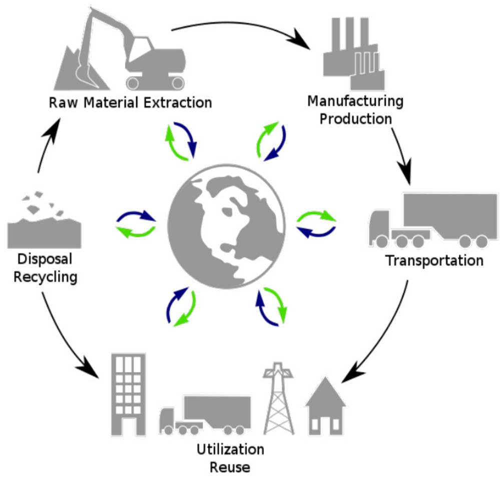


Figure 25: Product Life Cycle

Life cycle assessment is used to help understand the environmental impacts of goods and services through all stages of a life cycle. It seeks to identify what raw materials are used; what other products and processes are needed for manufacture; how the product or service is used; how it is disposed of and whether the associated transport or storage costs are environmentally significant. The ISO 14040 series on life cycle assessment provides guidance on the methodology. Knowing this product life cycle ensures that improvements made at one point in the life cycle do not create problems in others. It gives a clear picture of the overall environmental 'footprint'. For example, altering the chemicals used in a production process may make that aspect of the product's life cycle more eco-friendly, but only by evaluating the new end product can we determine whether the result is a more (or less) biodegradable product and whether the product is more sustainable over its whole life.

According to the LCA of simple shoes, material production and assembly determine about 90% of the environmental impact of shoe production. The remainder of environmental impacts is due to transportation, packaging and end-of-life scenarios.

EC Eco-Criteria for the product group footwear

Dangerous substances in the final product:

- For shoes made of leather, there shall be no chromium VI in the final product.

- There shall be no arsenic, cadmium and lead in the materials used for the product assembly or in the final product.
- The amount of free and hydrolysed formaldehyde in the components of the footwear shall not exceed 150 ppm in leather and not detectable in textile.

Reduction of water consumption (only for the tanning of hides and skins):

- The following limits shall not be exceeded: Hides: 35 m3/t , Skins: 55 m3/t.

Emissions from the production of material:

- If the waste water from tanning sites and textile industries is released directly into fresh water, the COD shall not exceed 250 mg/l.
- Tannery waste water after treatment shall contain less than 1 mg chromium/l.

Use of hazardous substances (up until purchase):

- Pentachlorophenol (PCP) and tetrachlorophenol (TCP) and its salts and esters shall not be used.
- No azo dyes shall be used that may cleave to any of the 22 banned aromatic amines.
- Any of the banned 9 N-nitrosamines shall not be detected in rubber.
- C10-C13 chloralkanes shall not be used in leather, rubber or textile components.
- No dyes meeting the criteria for classification as carcinogenic, mutagenic, toxic to reproduction or hazardous/dangerous to the environment shall be used.
- Alkylphenol ethoxylate (APE) and perfluorooctane sulphonate(PFOS) shall not be used.
- Only phthalates that at the time of application have been risk-assessed and have not been classified as dangerous can be used.
- Only biocides that are authorised for use in footwear shall be allowed for use.

Use of Volatile Organic Compounds (VOCs) during final assembly of shoes:

- The total use of VOCs during final footwear production shall not exceed, on average, 20 g VOC/pair.

Energy consumption:

- The energy consumption at the manufacturing stage shall be declared.

Packaging of the final product:

- Where cardboard boxes are used, they shall be made of 100% recycled material.
- Where plastic bags are used, they shall be made of at least 75% recycled material or they shall be biodegradable or compostable.

Information on the packaging:

- User instructions.

The following information shall be supplied with product:

- These shoes have been treated to improve their water resistance. They do not require further treatment (for water-resistant shoes).
- Where possible, repair your footwear rather than throwing them away. This is less damaging to the environment.
- When disposing of footwear, please use appropriate local recycling facilities where these are available.
- Information about the eco-label.

The following text shall appear on the packaging:

- Information to consumers: an information box in which the approach to environmental sustainability should be put on the packaging.
- Information appearing on the eco-label: the eco-label shall contain the following text:
- Low air and water pollution
- Reduced harmful substances
- Parameters contributing to durability
- Occupational and safety footwear shall carry the EC mark
- All other footwear shall meet the requirements indicated

Design for Environment

Design for Environment (DFE) is an approach that ensures environmental considerations are part of the product creation process, which is when the product is designed and developed. We should apply a DFE approach to our product creation process. Consideration should be given to the origin of the materials, usage of minimum materials for the product, and minimising emissions during manufacturing. DFE ensures that the final product will be safe for the user and only contains non-hazardous materials.
Using CAD

A company which has a high-quality design and development section is immediately in a much stronger position than one which depends on customers to provide design ideas and has a slow and inaccurate product development section. An ability to create its own designs allows a firm to choose its customers and gives it much better control over its selling prices. Having a good design and development section is also a sure sign of technical competence. Good product development almost always leads to efficient production and good quality. A factory that spends its time putting right the mistakes made in product development cannot produce at high speed and quality problems that are designed in can never by wholly eliminated in the factory.

Today CAD systems for shoe engineering are essential and there is a wide choice of systems to be used in shoe factories. Unfortunately many companies fail to exploit the benefits available from the use of such systems and in these companies the CAD function is little more than a computerised grading system. In sophisticated companies there is almost total linkage between the company's CAD system, its last makers, costing system, toolmaking and control data for computer-controlled machinery.

The quality of a design and development department can be assessed from three angles:

- productivity,
- punctuality and speed of development,
- accuracy of work (i.e. patterns put together properly first time).

Many development sections are highly unproductive and it is not unusual to see productivity of only a quarter of what it should be.

PI 7 PRODUCTION

PI 7.1 CUTTING / CLICKING

PI 7.1.1 – CUTTING BY PROPER NESTING

Placing the pattern to be cut from material like leather, sole, insole or synthetic follows scientific direction where waste is generated as minimally as possible. This is called cutting of cut component by proper nesting. Components cut from materials such as genuine or artificial leather, textile/canvas, rubber and leather board should include waste occurring due to the configuration of patterns (first waste), the differences in edges of components and materials (side or second waste) and imperfections in the genuine leather (fault or third waste).

Assessing the required genuine leather for a specific style is normally done by determining the so-called parallelogram area comprising the net pattern area and the unavoidable waste among the patterns. Different scientific and statistical methods (e.g. SLM – Scientific Leather Measurement, Shusterovich's method) exist in the footwear sector for calculating the material required for a pair of shoes including as minimum as possible waste for genuine leather.

On the other hand, standard percentages are used for estimating side waste in the case of man-made materials like textile, synthetic and artificial leather. The concept is to minimise the solid waste during cutting the materials, keeping the environmental impact into consideration. Some components (e.g. buckles, eyelets, heels, unit soles) are built into footwear construction without any (substantial) modification. Nevertheless, the rate of rejects in the supply should be taken into consideration.

The most important rules for cutting are dealt with in the section concerning material utilisation, because as far as leather cutting is concerned, it is almost certainly more important to cut economically than to cut fast. Almost all cutting speed benchmarks are therefore rather irrelevant particularly as the number of pieces in each shoe is rather variable. In leather cutting the standard swing beam press is the general rate but a number of 'environmental and ergonomic' good practices can improve overall performance levels. Calculation of leather consumption should be done by RSM (Russ and Small Method) or

SATRA Sum but SATRA Sum is computer-based and has very good accuracy.

Good lighting is crucial under the cutting machine. 1200-1500 lux is the correct level and it should be 'cool' lighting. Knife storage should be properly organised so that cutters do not waste time collecting knives. Good knife storage prevents damage to knives that avoid the need for 'double-bump' cutting that slows cutting and damages the cutting board. The removal of cut pieces should be efficiently organised. Scrap leather should be collected in bins/bags and not thrown on the floor. This allows inspection to see whether the cutting is close enough. Presses which have beams that swing into place automatically reduce fatigue.

The cutting of samples and small orders is being revolutionised by the introduction of computer-controlled continuous cutting machines. Initially these were mainly water jets and very expensive but more recently oscillating knife systems have become popular at a lower capital cost so that today good practice would be for even a smaller company to use this type of equipment and in fact the cost justification is often better for small companies. All these systems involve an operator actually making the cutting plan.

All shoe companies with reasonable financial resources should consider the installation of a computer-controlled continuous cutting system. The benefits can be particularly great for companies with a very diverse production and a good CAD system. Such systems:

- Allow a much quicker start of cutting of full ranges of sizes.
- Reduce tooling costs on models selling small quantities.
- Encourage the use of optimum patterns. Unsuitable initial patterns and material differences can be dealt with at low cost. The latter can save leather.

A specifically designed cutting machine should be used for cutting synthetic materials, such as a wide beam travelling head press, which allows pass-through feeding of material. A conventional leather press should not be used where rolls of material have to be pre-cut inefficiently and wastefully to allow the material to be brought under the cutting head. Gantries should be used for holding a number of rolls of material to allow efficient feed to the cutter. Self-levelling platforms can be used to feed sheet material efficiently to the cutting deck. Control of material use is essential but use of the CAD system to produce optimum cutting layout plans can be useful. Normally multilayer cutting should be the rule provided pattern distortion does not occur. But for smaller quantities of parts from a given material it may be more economical to cut single layer, this avoids waste in the preparation of much larger packs of material.

PI 7.1.2 – REUSE OF POLYMERS FOR SOLE MANUFACTURING

During the production of soles made of thermoplastic elastomers (TPE), a certain amount of waste is generated. Since almost all synthetic polymeric soles are non-biodegradable, their disposal poses serious problems. Recycling of thermoplastics elastomers has therefore become a subject of vital importance, considering the long-term environmental effects of waste disposal. The current concern regarding the disposal of industrial and post-consumer waste in diminishing landfill sites and the general impact of wastage on the environment have focused attention on developing effective reclamation and recycling policies in Bangladesh.

Thermoplastic elastomers show advantages typical of both rubbery materials and plastic materials. TPE materials have the potential to be recyclable since they can be moulded, extruded and reused like plastics, but they have typical elastic properties of rubbers, which are not recyclable due to their thermosetting characteristics. TPE also require little or no compounding, with no need to add reinforcing agents, stabilisers or cure systems. TPE can be easily coloured by most types of dyes. Besides that, it consumes less energy, and closer and more economical control of product quality is possible.

PI 7.2 STITCHING/ASSEMBLY

PI 7.2.1 – POOR FOLLOW-UP DESIGN SPECIFICATION IN THE STITCHING DEPARTMENT

A proper production line in the stitching department is instructed with design and technical specifications to be followed. Trained and skilled operators should follow these specifications at every workstation in order to avoid bottlenecks in production and avoid rejections. Poor follow-up design and technical specification may lead to increased rejections and eventually waste, which increases the production cost.

Alongside setting up well-organised production management, improved working methods and better utilisation of manpower, plant and equipment might reduce the practice of poor following of design specifications which might lead to reduce ineffective time. Hence overall performance and efficiency of the stitching department may increase.

The use of adhesive for bench operations such as folding, joining, upper and lining attaching should be reduced or avoided by using self-adhesive tape. The self-adhesive tape produces very good quality products since using adhesive in the bench operations produces stiffness at the folded or joining area of the upper. Solvent-based adhesive must be replaced by the water-based adhesive to avoid emission and toxicity of the solvent-based adhesive.

Good manufacturing practices (GMP) should be introduced in the closing section for sustainable development and quality production with increased productivity. For this, introducing the following is essential:

- A proper sequence of operation for closing of upper and lining parts since style variations are enormous in footwear; each article needs a proper sequence of operation to maintain quality and productivity.

- A proper systematic operating procedure (SOP) to operate machineries efficiently and effectively. This reduces the risks or accidents in the production area.

- A proper material handling system to improve quality and productivity. A modern automatic conveying system is required depending on the production capacity of the factory.

Achieving high efficiency in stitching is much more difficult than in any other part of the factory. This is due mainly to the high degree of sophistication required in management and training to achieve the best results, but it is also due to the fact that shoes vary enormously in what stitching needs to be done and by what machines. This sometimes makes it hard to justify the use of sophisticated work measurement techniques on styles where production runs are short. In addition, because shoes are so variable and the work content of different operations varies from shoe to shoe, the balancing of stitching departments is a key issue and requires considerable skill to achieve the best results.
Improvements to stitching machinery have taken two forms:

- Use of computer-controlled sewing machines that are only usable on certain types of product.

- Improvement of existing, mainly edge-following machinery such as post- and flat-bed stitching machines, skivers, folders, etc. by the addition of:

-
    - Quick-stop and variable-speed motors,

    - Needle-stop and needle-positioning devices,

    - Thread cutters,

    - A programming facility.

PI 7.2.2 – MINIMISATION OF TOLUENE-BASED ADHESIVE

In the footwear industry, this adhesive is widely used in sole attachment for bonding leather, synthetic upper, banwar, microsole, neolite sole, Texon board, etc. The adhesives used in shoemaking are solvent-based, water-based, radiation-cured (UV/EB), hot melts, etc. The problem associated with adhesives containing halogenated solvents, VOCs (benzene, xylene, o-cresol, p-cresol, m-cresol, etc.) and chlorinated aromatic hydrocarbons (chlorobenzenes and chlorotoluenes) have become a burning issue in Bangladeshi shoe industries.

Most shoe factories in Bangladesh are confronted with polyurethane (PU) adhesive which contains the restricted substance toluene as the solvent. However, adhesives should be free from toluene, benzene and halogenated hydrocarbon (trichloroethylene, dichloroethylene, 1,2-dichloroethane, methylene chloride, tetrachloroethylene, etc.).

There are a number of toluene-free adhesives in the international market. They are preferably composed of primarily a mixture of alicyclic and ketonic solvents. Viscosity: 1800 ± 100 cps at 30 ± 2 °C.

PI 7.2.3 – ASSEMBLY OPTIMISATION

A modular footwear concept can be implemented in order to reduce the use of adhesive, which can be replaced by mechanical locks.

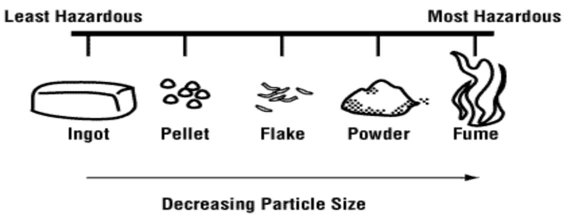
In addition, the use of seams instead of adhesives (where possible) is also an emerging sustainable practice.

The full replacement of solvent-based adhesive by water-based adhesive will be an eco-friendly practice in assembly and shoemaking operations. New alternative chemicals or substances can be used for the substitution of hazardous chemicals or substances. This is sometimes grouped with elimination because, in effect, this removes the first substance or hazard from the workplace. The goal, obviously, is to choose a new chemical that is less hazardous than the original.

The table below provides some examples:

Instead of:	Consider:
carbon tetrachloride (causes liver damage, cancer)	1,1,1-trichloroethane, dichloromethane
benzene (causes cancer), toluene	cyclohexane, ketones
pesticides (cause various effects on the body)	'natural' pesticides such as pyrethrins
organic solvents (cause various effects on the body)	water-detergent solutions

Another type of substitution includes using the same chemical but in a different form. For example, a dry, dusty powder may be a significant inhalation hazard, but if this material can be purchased and used as pellets or crystals, there may be less dust in the air and therefore less exposure.



PI 7.3 LASTING

PI 7.3.1 – PROPER MAINTAINING OF PRODUCTION PARAMETERS

A range of unit operations need to be followed in the shoe lasting department considering the product style and process parameters where the stitched upper is given a full shoe shape. The line of operation depends on material, style and design specification and the machines available. Proper maintaining of production parameters may lead to the decrease of repair and rejections.

At this stage of the shoemaking process, process parameters, for example, duration, temperature, line of action and pressure have to be followed properly. For instance, in back part moulding where the back part of the stitched upper is given a shape inserting stiffener in between the upper and lining is very important. The temperature and pressure of the back part moulding machine needs to be checked properly as per the requirements of stiffener to mould and finish the leather or synthetic upper. Even stitched upper should be placed on the back part moulding machine properly so that accurate back height can be achieved. A shoe size chart can be followed which describes the corresponding back height of each shoe size.

Similarly, process parameters like positioning and following the centreline in toe part lasting; seat and side lasting should be followed properly. Roughing and scouring beyond the margin should be avoided. Temperature and pressure in sole attaching and sole pressing should be maintained properly considering the type of upper, sole and adhesive used.

There are many different systems for transferring shoes from one worker to another in a lasting line. They include:

- Movable racks,
- Paced conveyors (conveyors moving at a set speed) – single tier,
- Variable-speed conveyors (usually multi-tier) of the duorail type,
- Rinks where the shoe is more or less handed from one operator to another.

The last two systems are those mainly used in modern factories. Paced conveyors do not generally produce high productivity though output is consistent.

Balance is critical. It is necessary to measure each operation in the lasting department and combine jobs so that as far as possible every worker is equally fully-loaded. This can involve splitting a job so that, for example, half the lasts are slipped from the shoes by the sole layer and the other half by the heel attacher.

Good manufacturing practices (GMP) should be introduced in the lasting and shoemaking section for sustainable development and quality production with increased productivity. For this, introducing the following is essential:

- A proper sequence of operation for lasting and making of upper and bottom parts since construction variations are enormous in footwear; each article needs a proper sequence of operation to maintain quality and productivity.

- A proper systematic operating procedure (SOP) to operate machineries efficiently and effectively. This reduces the risks or accidents in the production area.

Post-lasting operations should be automated to speed up and control pollution. Automatic roughing and cementing machines can be introduced to control emission and to improve quality and productivity. Sandstone grinding wheels on the roughing and scouring machine (cause severe respiratory illness due to silica) can be replaced by synthetic grinding wheels, such as aluminium oxide.

Water-based adhesive can be used for sole and upper bonding to avoid toxicity and air emission. Two-component PU adhesive is a better sustainable solution instead of using single-component PU adhesive since two-component PU adhesive avoids the use of very toxic hardener in its preparation. The best sustainable practice will be the attaching of the upper and sole by stitching, which fully avoids the use of adhesive.

PI 8 PRODUCT FINISHING

PI 8.1 – PROPER APPLICATION AND DISPOSAL OF FINISHING CHEMICALS

The misuse of finishing chemicals in shoe finishing is often confronted in the Bangladeshi shoe industry due to a lack of technical know-how, leading to a great threat of environmental pollution in the surroundings. Product knowledge and specification should be disseminated properly to the production line in order to minimise the excess and misuse of finishing chemicals and ensure their proper disposal.

For example, product knowledge of compatible shoe finishing for patent leather should be provided for those concerned in the shoemaking process. Because of the wrong selection of the shoe finishing, the aesthetic appeal of patent leather may be deteriorated. In other words, shoe finishing for aniline leather might not work for patent leather.

Ventilation is a method of control that strategically 'adds' and 'removes' air in the work environment. Ventilation can remove or dilute an air contaminant if designed properly. Local exhaust ventilation is very adaptable to almost all chemicals and operations. It removes the contaminant at the source so it cannot disperse into the work space. It generally uses lower exhaust rates than general ventilation (general ventilation usually exchanges air in the entire room).

Local exhaust ventilation is an effective means of controlling workplace exposures but should be used when other methods (such as elimination or substitution) are not possible. A local exhaust ventilation system consists of these basic parts:

- A hood that captures the contaminated air at the source;

- Ductwork that carries the contaminated air away from the source;

- A fan which draws the air from the hood into the ducts and removes the air from the workspace;

- Air cleaning devices may also be present that can remove contaminants such as dust (particulates), gases and vapours from the air before it is discharged or exhausted into the environment (outside air), depending on the material(s) being used in the hood.

Non-hazardous finishing chemicals such as cleaner, modifier, dyes, pigment, binder, shiner and shoe polish, etc. should be used in finishing operations. Water-based finishing chemicals can be used to avoid hazards and emission. Hazardous chemicals such as leaded glazes, paints, pigments (cause various effects on the body) can be substituted by versions that do not contain lead. The best sustainable practice in shoe finishing can be the usage of crust leather for making shoe upper instead of using finished leather. Diverse finished articles with different colours and shades can easily be produced with single crust leather upper and the shoe finishing cost is only 1.5-2.0% of the total production cost. In leather finishing, emission and pollution load is significant, and costing will be as well. Recycled and biodegradable packaging materials should be used in packaging the products. The introduction of the slim box can be a good sustainable practice in packaging.

Finishing productivity is hard to measure because no one can tell exactly how many times it is necessary to polish a piece of leather. Finishing departments have some operations that occur on all shoes, such as:

- Putting in the sock
- Boxing
- Attaching trimming
- Inserting laces
- Dealing with problems, as where the leather finish has come off

This means that the finishing department needs a lot of flexibility.

The problems of the component and stock section of a factory are made more difficult by the fact that the work needing to be done changes dramatically with the season and with the type of shoes being made. For many factories this means that production lines have to be reorganised very often. This is why in many factories this department is badly organised, has low productivity and is very untidy.

PI 8.2 – REUSING AND RECYCLING SOLID WASTE

The absence of a proper disposal network of solid waste leaving the shoe industry has been a great threat to the environment. The proper segregation of solid waste can provide a solution to minimise the product cost and environmental pollution.

For example, metal containers for the steel or cast iron industry, used plastic jars for the plastic material industry as secondary polymer, isolated thermoplastic elastomeric soles from rejected shoes for sole making as secondary polymer, etc.

Furthermore, solid waste like scrap leather and rejected shoes can be reused for making leather board.

PI 9 FULL PRODUCT PACKAGING

PI 9.1 – MINIMUM MOISTURE CONTENT

The fungal growth in shoes inside the shoe box is often a complaint about the Bangladeshi shoe industry. There are many complaints about huge business losses due to fungal growth resulting in discolouration or stains in leather during shipment of shoes from Bangladesh to other parts of the world like the EU and other countries. Though anti-fungal reagents are used during the manufacturing of leather and even in leather shoe finishing, fungal growth is not always avoided.

Moreover, fungal growth is a problem even after the moisture absorber pack (granules of copper sulphate) is placed in the shoe box. The problem is associated with the moisture content and relative humidity in leather. It is scientifically proven that if the moisture content of leather is 15% or more, there is a possibility of having fungal growth in leather shoes, resulting in fading out or discolouration of leather or stains in the shoe upper. Hence it is advisable to use quality moisture absorber which can retain moisture content of < 15% in the shoe box during product shipment. Apart from that, product shipment should be executed in controlled containers where optimum temperature (< 25 °C) and relative humidity (65% ±5%) can be achieved throughout the journey of the product shipment in order to prevent fungal growth in shoes. Micropack should be used in packaging instead of conventional silica gel (restricted) as moisture absorber.

PI 9.2 – PACKAGING MATERIALS

Packaging can be optimised by reducing its size and weight, and by using recycled and recyclable materials. The use of recycled paper or bioplastics as shoe box fillers is also advisable.

PI 10 END OF LIFE

PI 10.1 – RECYCLING

The end-of-life waste can be re-introduced back into the market through a series of processes that can be divided into two major methods: destructive and non-destructive.

Destructive methods, like shredding, could be used to transform shoes into other useful materials. End-of-life shoes are being collected and taken to recycling facilities where they are shredded without separation into material types, in order to produce materials that are used in secondary applications such as surfacing for roads, playgrounds and operating trucks. For example, a mechanical grinding process can be used to facilitate material recovery and incorporating the salvaged material into a variety of applications such as surfacing materials, insulation boards and underlay products. The footwear industry will also be able to use the salvaged materials to make new soles and insoles.

Non-destructive methods involve the dismantling of shoes to recover saleable and reusable components and to isolate materials for further recycling and disposal. Non-destructive methods generally include inspections, disassembly, replacing and repairing shoe parts and components and finally re-assembling them into a new product that could be used inside or outside the footwear sector. However, disassembly of EoL shoes is not an easy task, typically due to the large amount of adhesive used to join shoe parts together along with stitching techniques. New technologies must be employed to aid the eventual disassembly process, for example, the use of water-soluble adhesives and the use of construction techniques that require less stitching.

PI 10.2 – ENERGY RECOVERY FROM WASTE

EoL waste can be recovered in order to generate heat and electricity. Energy recovery from waste includes a number of established and emerging technologies such as incineration, gasification and pyrolysis. In the case of leather waste, gasification technology has been applied for heat generation and chromium recovery.

Disposal of waste is often regarded as the last resort waste management option with the highest environmental impact. Most of the EoL footwear waste is going to landfill sites to be deposited. However, not all waste can be prevented or recycled and there will always be some waste to be disposed of in landfills or even just thrown away.

PI 10.3 – END-OF-LIFE MANAGEMENT OPTIONS FOR BIODEGRADABLE MATERIALS

There are two established methods for the end-of-life management of biodegradable materials: biological treatment and conventional methods.

Biological treatment includes both aerobic (composting) and anaerobic digestion. Aerobic composting of biodegradable materials generates carbon dioxide, water and methane, as well as some form of compost, which can be used as a fertiliser.

Anaerobic digestion, on the other hand, is a process where biodegradable material is broken down in the absence of oxygen in an enclosed vessel. The process produces carbon dioxide, a biogas and solids/liquors known as digestate which can also be used as fertiliser.

Biodegradable waste materials can also be treated using conventional methods, such as incineration and landfilling. These methods may be a solution if there is no available biological treatment. The EU Landfill Directive requires a considerable reduction to the volume of biodegradable materials being sent to landfill and even such materials are being excluded from landfilling by law.

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