SYLPROJECT
Sustainable Yak Leather

'Capacity building to the Mongolian vegetable-tanned yak leather cluster on bio-leather and bio-leather products'

Guide on the implementation of low energy and emission finishing operations

switchasia
Funded by the European Union

Publicity Disclaimer

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of the SYL consortium and do not necessarily reflect the views of the European Union.

ABBREVIATIONS AND ACRONYMS

BAT	Best Available Technology
BOD_5	Biological Oxygen Demand, five days
BREF	Best Available Techniques Reference Document
COD	Chemical Oxygen Demand
COTANCE	Confederation of National Associations of Tanners and Dressers of the European Community
EU	European Union
FILK	Forschungsinstitut für Leder- und Kunststoffbahnen gGmbH
HVLP	High-volume Low-pressure
ICEC	Institute of Quality Certification for the Leather Sector
IPPC	Integrated Pollution Prevention and Control
IUE	Environment Commission of the International Union of Leather Technologists and Chemists Societies (IULTCS)
LWG	Leather Working Group
OSH	Occupational Safety and Health
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SDG	Sustainable development goals
SS	Suspended Solids
SYL	Sustainable Yak Leather project
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
UN	United Nations
UNIDO	United Nations Industrial Development Organization
UV	Ultraviolet
VOC	Volatile Organic Compound
ZDHC	Zero Discharge of Hazardous Chemicals

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FOREWORD

The biggest contribution to improvements in the operations of the tanneries belonging to the Vegetable Tanned Yak Leather Cluster is expected to be the change from '*coated*' leather to '*full grain'* production. The pigments, bindings and coatings applied in '*coated leathers'* can be up to 0.5 or 0.6 mm thick, in men's shoe uppers for example. But this layer should (by definition) be no more than 0.15 mm (preferably less) in '*full grain'* leather. This change alone could reduce the Cluster members' consumption of finishing chemicals (along with energy, water, etc.) to a quarter of previous levels.

This guide was prepared by the Sustainable Yak Leather (SYL) Project based on previous studies conducted by IUE[1] Commission, United Nations Development Organisation (UNIDO) and the European Commission, among others. It is intended to provide relevant technical advice and support to tanneries' staff for the establishment and implementation of low energy and emissions finishing operations in the production of vegetable-tanned yak leather.

Details of finishing practices used by Cluster members' were expected to provide the basis of a dedicated section in this guide; *5. Existing Operations*. Unfortunately, information on this topic (as with some others) was not available. However, personal observations and anecdotal evidence indicate considerable scope for improvements in Cluster members' finishing practises. Documentation of practices – and preferably the adoption of, and adherence to, standard operating procedures – remain a priority issue for attention throughout the production of leather, and manufacture of leather products.

Implementation the of the low energy and emission finishing operations described in this guide are expected to contribute to the UN *Sustainable Development Goals* (SDGs); especially *SDG 12 Responsible Consumption and Production.* Processing of yak hides, is part of much larger tanning and leather goods manufacturing operations in Mongolia, involving considerably larger numbers of hides and skins (of cattle, horses, sheep and goats). Though these other operations involve mineral (chrome) tanning - rather the vegetable tanning used in the SYL project – some of the techniques (and all of the underlying justifications) are equally applicable throughout the textiles, clothing, leather and footwear sector.

[1] Environment Commission of the International Union of Leather Technologists and Chemists Societies

1. INTRODUCTION

The purpose of finishing is to protect leather against soiling, staining and water penetration, but also to provide it the desired (uniform) appearance, flexibility, colour, gloss or dullness and handle. Furthermore, depending on the end use, the finish has to meet some specific performance characteristics regarding dry and wet fastness, water vapour and perspiration permeability and high resistance to staining by water droplets.

To achieve these aims leather is subject to a series of processes and operations with many variations adapted to raw material and requirements by individual customers while also taking into account environmental, occupational safety and health (OSH) aspects and even weather conditions.

The commonly used mechanical operations in the finishing department are:

- Conditioning (optimising the moisture content as described previously).
- Staking (softening and stretching of leather).
- Dry milling.
- Polishing.
- Embossing.
- Plating (flattening).

Some of these operations (e.g. staking) may be carried out: in the wet and dry finishing departments, before and/or after applying a coating, and/or between the applications of coatings. To achieve specific grain appearance/effects or to hide grain defects, additional operations are needed, like buffing of the leather surface followed by dedusting.

The purpose of buffing the grain side is to clean and smooth it. An exception is when the product is suede; its fine nap achieved by a series of buffing runs with abrasive paper of different grit sizes.

Drying, usually in a tunnel with steam, gas or electric (infrared) heating, is obligatory regardless of the method of applying finishes.

Leathers can have one or multiple coatings, depending on the properties required. Most of the time the coatings are film forming; typically, leathers have a pigmented base coat and intermediate coat and a transparent topcoat. Coatings are applied by spray, roll coaters, curtain and paper transfer and are mostly water based.

Conventional coating by spraying results in considerable losses of coating material. Measured in terms of key pollution parameters (COD, BOD, and SS) and the amount of wastewater discharged at the finishing stage, polluting emissions are quite insignificant in comparison with the beamhouse and tanning department. However, environmental threats due to use and emissions of pigments, organic solvents (VOCs), airborne particles and malodours (in old poorly ventilated areas) are quite serious. And the negative impacts of vibrations, dust and noise cannot be ignored either. All these hazards are compounded by the high risk of fire hazards, which make old finishing departments possibly the most potentially harmful to workers' health. Evidently, good housekeeping and monitoring finish usage, equipment optimisation (especially spraying), avoidance of re-work, etc. are also important in reducing the negative environmental impacts of finishing operations.

In roller coating the finish is applied by grit rollers to the surface of the leather, similar to the process used in printing. 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. Avoidance of the mist and solid particulate emissions associated with spraying is also beneficial. The operational data will entirely depend on the product that is being produced. Coating wastage rates of 3 – 5% are reported as opposed to 40% for conventional spraying.

Also, some processes may be very high energy consuming, also posing a challenge in terms of environmental sustainability. "*Low energy leather finishing*" typically refers to the process of applying a protective and/or decorative finish to leather products using methods that minimise energy consumption and environmental impact. This approach aligns with sustainability goals by reducing the use of energy-intensive processes and potentially harmful chemicals.

2. ENERGY AUDIT

2.1. Objectives

In order to opt for different strategies for energy and emission reduction in leather finishing, it necessary to carry out an individualised study of the energy issues affecting each particular tanner, to evaluate ways to optimise their energy efficiency. An energy audit in leather finishing involves a comprehensive analysis of energy consumption and efficiency within the leather finishing process. The goal of an energy audit is to identify opportunities for reducing energy usage, improving operational efficiency, and ultimately minimizing costs and environmental impact.

The box shows some of the most relevant certification and audit bodies active in the leather industry, with data regarding the European sector.

	DESCRIPTION	SERVICES	TOTAL TANNERIES	EUROPEAN TANNERIES
SUSTAINABILITY CERTIFICATION ICEC	Environmental, social and quality / product certifications based on official standards. ICEC is the industry-led institute for Quality Certification in the leather sector	• Environment (ISO 14001, EMAS, PEF schemes, etc.) • Social (ISO 45001, Social Accountability) • Quality and product (ISO 9001, MADE IN, traceability and chemicals management (REACH, ZDHC, etc.)	130 280 certifications	85%
LEATHER WORKING GROUP	Environmental compliance and performance protocols and audits developed by the Leather Working Group Ltd, a multistakeholder group	• Environment Audit Protocol for leather manufacturers • Trader Assessment Protocol for traders of part-processed and finished material • Chemical Management Module for leather manufacturers	550	20%
ECOL Energy Controlled Leather	Auditing model determining the energy efficiency and the CO_2 emissions of a tannery controlled by a research & test institute, FILK	Label for energy efficiency and CO_2 emissions of a tannery	25	56%
TANNERY OF THE YEAR 2020	Awards programme for the global tanning industry, launched by World Leather magazine	Various awards at different levels celebrating tanning excellence	6	33% + 6 finalists

OEKO-TEX® LEATHER STANDARD	Modular certification system offered by Oeko-Tex, an association of 18 textile and leather testing institutes in Europe and Japan	• Products: LEATHER STANDARD • Production: STeP (Sustainable Textile and Leather Production) • Use of chemicals: ECO PASSPORT • Product/Production: MADE IN GREEN	46	48%

(Source: COTANCE, 2020)

The LWG Leather Manufacturer Audit Standard is the Leather Working Group's flagship auditing protocol, designed to holistically assess the environmental, social and governance of leather manufacturers across the leather supply chain. The audit standard comprises a rigorous assessment across 17 sections, including a facility's energy and water usage, management of waste, effluent, and chemicals, as well as health and safety, traceability, and a recently introduced social audit recognition.

2.2. Methods

The following is a general outline of the steps involved in conducting an energy audit in leather finishing:

1. **Data collection and process mapping:**
   - Gather detailed information about the leather finishing process, including the various stages, equipment used, and energy sources.
   - Create a process flow diagram to visualize the entire production process and energy consumption points.

2. **Energy consumption analysis:**
   - Measure energy consumption at different stages of the leather finishing process, including heating, cooling, drying, and other energy-intensive activities.
   - Identify the major energy-consuming equipment, such as drying ovens, compressors, boilers, and ventilation systems.

3. **Data analysis and benchmarking:**
   - Compare the businesse's energy consumption data with industry benchmarks or similar facilities to assess how efficiently you're using energy.
   - Analyse historical energy usage patterns to identify trends, peak demand periods, and potential inefficiencies.

4. **Identification of energy conservation opportunities:**
   - Conduct a thorough walkthrough of the facility to identify potential energy-saving opportunities. These could include improving insulation, optimizing equipment settings, upgrading to energy-efficient equipment, and implementing process changes.
   - Prioritize identified opportunities based on their potential energy savings, implementation cost, and payback period.

5. **Energy efficiency measures:**
   - Implement energy-saving measures such as upgrading to energy-efficient lighting, improving insulation, optimizing equipment operations, and implementing heat recovery systems.

- Consider adopting automation and control systems to better regulate energy usage based on actual production needs.

6. **Monitoring and measurement:**
   - Install energy meters or sub-meters to monitor energy consumption in real-time. This data can help track the effectiveness of implemented measures and identify any anomalies.
   - Regularly review and analyse energy consumption data to ensure that the implemented measures are delivering the expected savings.

7. **Employee training and engagement:**
   - Educate employees about energy-efficient practices and the importance of energy conservation.
   - Encourage employee involvement in identifying energy-saving opportunities and reporting any energy wastage.

8. **Reporting and documentation:**
   - Compile a detailed energy audit report that outlines the current energy consumption, identified opportunities, recommended measures, and potential savings.
   - Include cost estimates, payback periods, and any financial incentives or rebates available for implementing energy-efficient measures.

9. **Continuous improvement:**
   - Energy management is an ongoing process. Regularly review the energy audit results and continuously seek new ways to optimize energy usage and reduce costs.

2.3. Analysis of results

By conducting a thorough energy audit and implementing energy-efficient measures, leather finishing facilities can significantly reduce their environmental impact, cut down operational costs, and contribute to sustainable production practices. It is important to tailor the audit process to the specific requirements and processes of the facility while keeping an eye on the latest energy-saving technologies and practices in the industry.

3. EMISSIONS

3.1. Types and characteristics

Finishing involves two coating steps; the application of a base coat and a topcoat. The base coat mainly involves the application of solvents and binders able to interact with the surface of crust leather, thus modifying its chemical properties and allowing the fixation of pigments and dyes. The topcoat protects the finished leather surface by means of lacquers or polyurethanes. To achieve high performance, the base and topcoats need to be highly compatible; the base coat, indeed, acts as a bridge between the leather and the topcoat.

Finishing formulations also comprise film-forming agents, which can be classified into resin-based and protein-based formulations. Resin-based formulations confer high standard properties, such as colour fastness and hydrophobicity, although they often contain polluting and toxic compounds. Protein-based formulations provide a more natural appearance, with casein being the most widely used and well-known binder for this type of finishing. Casein-finished leather is characterised by brightness and thermostability; however, it presents low water resistance and rub fastness. Several methods to improve the properties of protein-based formulations have been developed, mainly based on cross-linking agents capable of increasing film-forming capability.

Environmental threats due to finishing operations are mainly based in the emissions of VOCs, airborne particles and malodours in old poorly ventilated areas. Emissions of solid waste and wastewater are produced in smaller quantities and, therefore, they are less important.

Furthermore, the toxicity of chemicals, such as formaldehyde, other organic solvents and certain cross-linking agents might constitute a severe problem if they are released. Formaldehyde may be released where protein finishes are used, or wool-on sheepskins are ironed.

The main emissions derived from leather finishing operations are described below.

3.1.1 Organic solvents – Volatile organic compounds

Organic solvents are used as carriers in the formulation of the finish. However, as a rule they are also already contained in commercial finishing products (e.g. lacquers) very often without indication about the type and quantity of organic solvent used.

The main problem with organic solvent-based coating agents is the emission of volatile organic compounds (VOCs) released during and after the coating process and there are considerable variations. The issue of VOC emissions in the leather industry were largely triggered by the so-called fogging problem related to the automotive industry but subsequently issues like smell and toxicity were also auxiliaries used in the finishing process may contain halogenated organic compounds.

According to European Union (EU) legislation, organic compounds are classified as VOC if their vapour pressure at 20 °C or at application temperature respectively is more than 0.1 hPa. In the USA it is the compounds that take part in photochemical reactions in the atmosphere.

A number of organic compounds are directly harmful to human health or to the environment. Moreover, many organic solvents undergo chemical reactions in the atmosphere that cause a number of indirect effects, in particular the formation of photochemical oxidants and their main constituent, ozone. Pollution by tropospheric ozone is a widespread and chronic problem.

Due to their persistency and accumulation in the biosphere, halogenated hydrocarbons and, in particular, highly volatile halogenated hydrocarbons, are subject to special attention and relevant legislation. Certain halogenated organic compounds are ozone-depleting substances and in compliance with the Montreal Protocol have to be phased-out.

Untreated organic solvent emissions from the finishing process can vary between 100 and 3,500 mg/m^3 in conventional processes. About 50% of measurable emissions arise from spray-finishing machines, 50% from dryers. Fugitive emissions to the air and solvents in wastes account for the rest of solvent consumption. The leather industry as a whole has considerably reduced its solvent use. For example, in some parts of Europe the consumption of organic solvents in finishing in the last 15 years has more than halved.

3.1.2 Airborne particulate matter

The main emissions of airborne particles in finishing emanates from buffing where leather surface is abraded; the particles are wet or dry and with a high organic content.

Buffing dust concentrations vary widely (0.1 to 30 mg/m³) depending on the space and equipment in place. An efficient extraction ventilation system fitted with bag filters or wet scrubbers is a must; in the EU the efficiency norm to meet is 3 to 6 mg/m^3 of exhausted air expressed as a 30-minute mean. It is also necessary to reduce the noise pollution from the exhaust system itself, which can be considerable; the design, selection and positioning of fans is thus very important.

A disposal route for the dust collected is not easy to find, in some cases it is taken away, compacted and briquetted.

3.1.3 Solid waste and wastewater

Solid wastes in finishing are mainly residues from finishing mixtures and sludges from air pollution abatement systems. In some tanneries, particulate matter is compacted and briquetted after being collected by various systems. These residues are wastes for which a use or disposal route must be found.

Table 1 Solid waste generation from leather finishing

Solid waste	Quantity (kg/ton of raw material)
Buffing dust	1
Finished leather trimmings	5
Total leather manufacturing	637

(Source: UNIDO. 2019)

Wastewater comes from the finishing and equipment cleaning; while the volume of wastewater is insignificant, the water can be heavily polluted by the presence of organic solvents, pigments containing some metals as well as hazardous chemicals present in other finishing materials such as cross-linkers and auxiliaries. If a wet scrubbing system is used, the slurry produced is a waste for disposal. Recycling the washing water can reduce the water consumption.

3.2. Scope for control

The challenge is to achieve a reduction of VOC emission by the avoidance of harmful cross-linkers and the improvement of coating efficiency.

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, as 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. Ideally, VOC free finishing systems should be based on renewable resources.

In relation to the solid waste management, the challenge is the complete utilisation and the avoidance of land disposal. Prevention and control measures for solid waste include the following:

- Reduce inputs of process agents (particularly precipitation agents in wastewater treatment) to the extent practical.
- Segregate different waste/residue fractions to facilitate recovery and re-use (e.g. to manufacture pet toys, pet food, leather fibreboard, etc.).
- Recycle sludge as compost/soil conditioner or in anaerobic digestions for energy generation. Process sludge may be used for composting/agriculture after appropriate assessment for contaminants and potential impacts to soil and groundwater.
- Dispose of non-recoverable and non-recyclable waste and sludge by appropriate methods, depending on the waste hazard classification.

Measures to prevent these chemicals from entering the wastewater stream include the following:

- Avoid the use of halogenated compounds.
- Recover impregnating agents from effluents.
- Avoid the use of azo dyes with carcinogenic amines (e.g., diphenil-4amine, benzidine).
- Substitute organic solvent-based dyes with nonhalogenated and solvent / water-based and water-soluble dyes for dyeing and finishing operations.

Effluent levels for tanning and leather finishing		
Pollutant	**Unit**	**Guideline Value**
pH	Standard units	6-9
BOD_5	mg/L	50
COD	mg/L	250
Total Suspended Solids	mg/L	50
Sulphide	mg/L	1.0
Chromium (hexavalent)	mg/L	0.1
Chromium (total)	mg/L	0.5
Chloride	mg/L	1,000
Sulphate	mg/L	300
Ammonia	mg/L	10
Oil and greases	mg/L	10
Total nitrogen	mg/L	10
Total phosphorous	mg/L	2
Phenols	mg/L	0.5
Total coliform bacteria	MPN[a]/100 ml	400
Temperature increase	ºC	> 3[b]
Notes: [a] MPN: Most Probable Number [b] At the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use, potential receptors and assimilative capacity.		

Air emission levels for leather finishing	
Pollutant	**(kg of HAP loss per 100 m^2 of leather processed)**
Upholstery leather (= 4 grams add-on/square feet)[2]	1.3 / 0.2
Upholstery leather (< 4 grams add-on/square feet)	3.3 / 1.2
Water-resistant / Specialty leather	2.7 / 2.4
Non-water-resistant leather	1.8 / 1.1
Source: Hazardous Air Pollutants as noted in United States 40 CFR, Part 63, Subpart TTTT.	

(Source: IFC. 2007)

Substitution of substances in finishing operations:

- Aqueous finishing systems
- Substitution of particular organic solvents
- Agents with low aromatic content
- Substitution of heavy metals in pigments
- Substitution of binders and cross-linking agents
- substitution of biocides.

[2] Despite the widespread use of the *International System of Units* (SI), imperial measures remain common in many aspects of the leather industry; for the measurement of area in particular. One square foot (1.0 ft^2) is equal to 0 0.0929 m^2)

3.3. Restrictions on emissions

Leather finishing involves various processes to enhance the appearance, texture, and durability of leather products. These processes can release emissions and pollutants into the environment if not properly managed. Many countries and regions have established regulations and guidelines to control and restrict emissions from leather finishing operations. It's important to note that these regulations can vary widely depending on the jurisdiction and the specific chemicals and processes involved. Here are some general points to consider regarding restrictions on leather finishing emissions:

1. **Volatile Organic Compounds:** VOCs are chemicals that can evaporate into the air and contribute to air pollution and smog formation. Leather finishing processes often involve the use of solvents and coatings that contain VOCs. Many regulations set limits on the amount of VOCs that can be emitted from these processes. Leather finishing facilities may need to invest in VOC capture and control technologies to meet these limits.

2. **Air quality standards:** Regulatory agencies often establish air quality standards that define acceptable levels of pollutants in the air. Leather finishing operations may be subject to these standards, and emissions from their processes must not exceed the allowable limits to avoid air quality degradation.

3. **Wastewater discharge**: Leather finishing processes can generate wastewater containing chemicals and contaminants. Regulations typically govern the discharge of these wastewater streams into public sewage systems or water bodies. Leather manufacturers may be required to treat their wastewater to remove or reduce pollutants before release.

4. **Chemical usage and restrictions**: Certain chemicals used in leather finishing may be restricted due to their environmental impact or potential harm to human health. Regulations may limit or ban the use of specific chemicals, and manufacturers must comply with these restrictions.

5. **Reporting and compliance**: Leather finishing facilities may be required to report their emissions and chemical usage to regulatory authorities regularly. Compliance with emission limits and other regulations may be subject to regular inspections and audits.

6. **Technology and best practices**: Manufacturers are often encouraged or required to adopt cleaner production technologies and best practices to minimize emissions. This might include the use of water-based coatings instead of solvent-based ones, implementing efficient ventilation systems, and investing in pollution control equipment.

7. **Labelling and certification**: Some leather products may be required to meet certain environmental standards to be labelled as "*eco-friendly*" or "*low emission.*"

Certifications from recognized organizations can provide consumers with assurance that the products meet specific environmental criteria.

8. International agreements: Certain international agreements, such as the Stockholm Convention on Persistent Organic Pollutants, can influence the use and handling of chemicals in leather finishing on a global scale.

It is important for leather finishing facilities to stay informed about local, national, and international regulations that apply to their operations. Compliance not only helps protect the environment but also ensures that businesses can operate sustainably and avoid potential legal issues. Keep in mind that regulations can change over time, so staying updated is crucial.

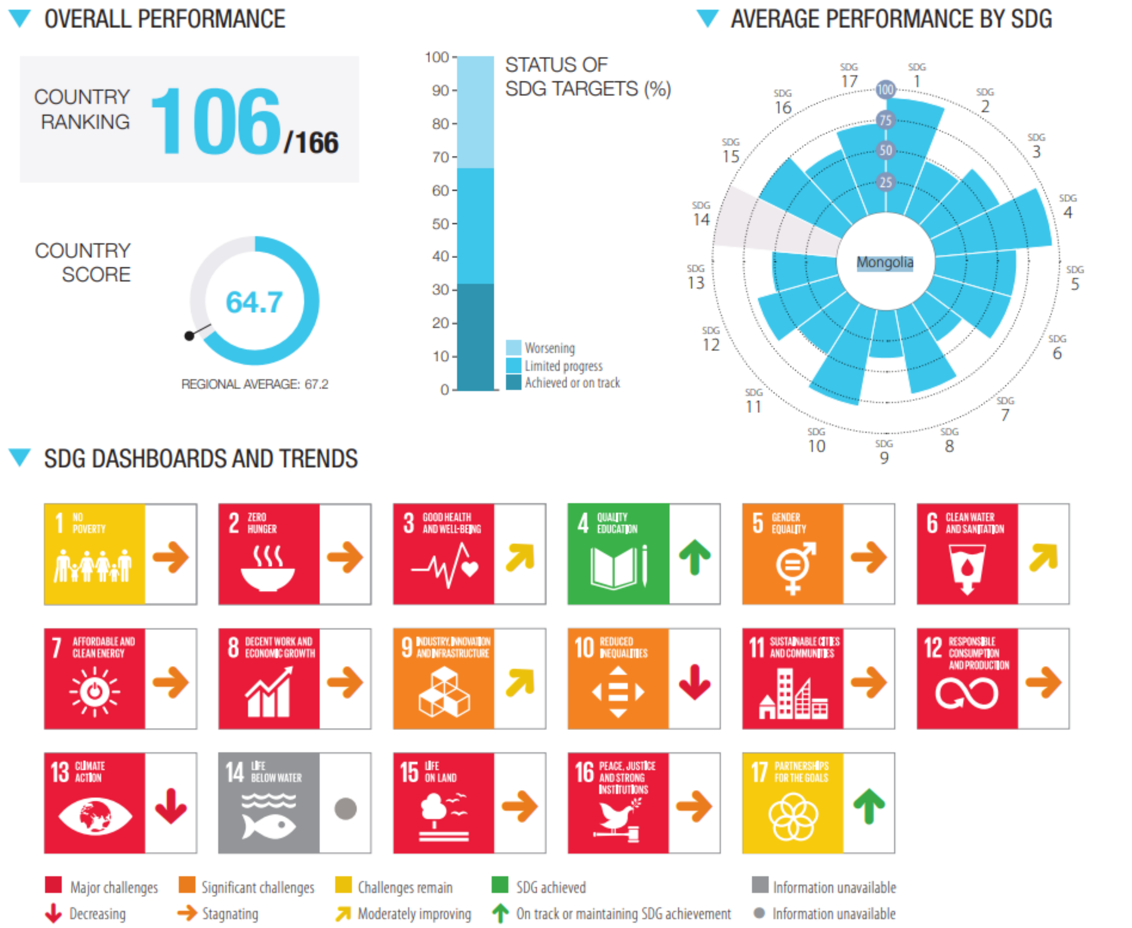
4. SDG12. RESPONSIBLE CONSUMPTION AND PRODUCTION

SDG 12 Responsible Production and Consumption is one of 17 goals adopted in 2015 by the 193 members of the UN (including Mongolia). The package of goals were to be accomplished over the following 15 years, and are described within the *2030 Agenda* (and Mongolia's *Sustainable Development Vision 2030*, 2016, 54 pages). The SDGs are a follow-up to the proceeding *Millennium Development Goals*; though somewhat more numerous and with detailed targets and defined indicators.

Many of the SDGs are interconnected, and all have at least some relevance to the textiles, clothing, leather and footwear sector. However, the one most closely related to the SYL project is *SDG 12 Responsible Production and Consumption*; which has 11 target, and associated indicators.

#	Target	Indicator
1.	Implement the 10-year sustainable consumption and production framework	**12.1.1.** Number of countries with sustainable consumption and production (SCP) national action plans or SCP mainstreamed as a priority or a target into national policy.
2.	Sustainable management and use of natural resources	**12.2.1.** Material footprint, material footprint per capita, and material footprint per GDP. **12.2.2.** Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
3.	Halve global per capita food waste	**12.3.1**. Food Loss Index which focuses on losses from production to consumption level. **12.3.2.** Food Waste Index this indicator is a proposal under development
4.	Responsible management of chemicals and waste	**12.4.1.** Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement. **12.4.2.** Hazardous waste generated per capita, and proportion of hazardous waste treated, by type of treatment.
5.	Substantially reduce waste generation	**12.5.1**. National recycling rate, tonnes of material recycled.
6.	Encourage companies to adopt sustainable practices and sustainability reporting	**12.6.1**. Number of companies publishing sustainability reports.
7.	Promote sustainable public procurement practices	**12.7.1.** Degree of sustainable public procurement policies and action plan implementation.
8.	Promote universal understanding of sustainable lifestyles	**12.8.1.** Extent to which global citizenship education, and education for sustainable development are mainstreamed; in national education policies, curricula, teacher education, and student assessment.
9.	Support developing countries' scientific and technological capacity for sustainable consumption and production	**12.9.1.** Installed renewable energy-generating capacity in developing countries (in watts per capita)".[1]
10	Develop and implement tools to monitor sustainable tourism	**12.10.1. I**mplementation of standard accounting tools to monitor the economic and environmental aspects of tourism sustainability.
11.	Remove market distortions that encourage wasteful consumption	**12.11.1.** Amount of fossil-fuel subsidies as a percentage of GDP, and amount of fossil fuel subsidies as a proportion of the total national expenditure on fossil fuels.

Currently (half-way through the time allotted to achieving the SDGs) Finland is the leading country in term of accomplishments, with a score of 86.8 (out of a maximum of 100). Conversely, South Sudan is trailing in 166th place with a score of 38.7 (*Sustainable Development Report*; 2023. Sustainable Development Solutions Network, 546 pages). Mongolia - in 106th place with a score of 64.7 - is positioned somewhere in the middle.



Though Mongolia's performance across the range of SDGs is somewhat mixed, moderate improvements in two goals relevant to the SYL project (SDGs 6 and 9; Clean Water and Sanitation, and Industry Innovation and Infrastructure) are obvious. Further progress within SDG 6 in particular are likely with the impact of stricter controls upon effluent discharges in and around Ulaanbaatar. Many of the country's tanneries and leather goods manufacturers are still located in the capital where 50% (1.7 million people) of the population resides.

Among the more numerous SDGs where progress is described as '*stagnating*' is *SDG 12 Responsible Production and Consumption*. Most of the 11 constituent targets are very relevant to livestock production in general - and tanning and leather goods manufacture in particular – but two are especially so:

4. Responsible management of chemicals and waste
5. Substantially reduce waste generation

Excessive quantities of sometimes inappropriate) chemicals – along with large quantities of water and energy provide lots of scope for reduction, reuse, and/or recycling; especially during finishing. Similarly, the is considerable wastage in the production and processing of all hides and skins (not just those of yaks). Examples rage from the avoidable losses in livestock during herding, to the discarding and/or re-working of leathers adversely affected by (avoidable) pre-slaughter defects.

5. BEST PRACTICES IN LEATHER FINISHING

5.1. Approaches for controlling VOC emissions

Water-based finishing

Water-based finishing allows organic solvents – VOC emissions – to be reduced by:

- Full replacement of organic solvents with water-borne coatings (e.g. by replacing lacquers with hard resin topcoats).
- Partial replacement (e.g. replacing lacquers with lacquer emulsions).
- Use of advanced extraction ventilation and abatement systems (wet scrubbing, adsorption, bio-filtration and/or incineration).
- A combination of the above methods, with particular attention to the coating techniques themselves.

Completely organic solvent-free finishing is still not available. However, while the organic solvent content in organic solvent-based lacquer is 80-90%, in water-based lacquer emulsions the solvent content is about 40%, and in fully, water-based systems it is only 5-8%. Provisions for organic solvent recycling include a careful selection of organic solvents; otherwise, recycling can be impossible.

For cleaner finishing selection and application of cross-linkers, careful consideration and control are needed. Similarly, water-based spray dyes should be used to the greatest possible extent.

The release of VOCs requires special abatement techniques. Organic solvent-based processes in closed spray cabinets and closed drying systems (which offer an acceptable environmental performance) require cost-intensive abatement techniques.

Scrubbers create an effluent, containing finish mixes and water-miscible organic solvents. Organic solvents that are not water-soluble will be emitted into the air. Equipment for wet scrubbing of the exhaust air has become a standard installation in most spraying units, in order to eliminate dust particulate and aerosols.

In assessing VOC emissions, distinction has to be made between the applied solvents, according to their toxicity. The spray booth must be closed during processing in order to minimise emissions from the over-spray (aerosols, organic solvents) into the working environment. Extracted air requires treatment to reduce particulate and organic solvent emissions.

In the finishing process, water-based systems are increasingly favoured because of environmental concerns about organic solvents, and in order to comply with regulations. 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 less toxic and less volatile forms. Nevertheless, appropriate safety precautions are required when handling and applying these agents.

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 (to make recycling feasible) avoid mixtures.

High-volume low-pressure (HVLP) spray guns

The air column from the conventional spraying gun (pressure about 2.0 bar) carrying finishing articles, bounces back from the leather surface resulting in a loss of 55-65% of finishing material. HVLP spray guns spray with a large volume of air at low pressure (only about 0.7 bar) can be used so that the 'bounce-back' is considerably reduced in comparison with conventional spraying. The HVLP technique does not give completely satisfactory results for some articles, such as shoe upper leather and garment leather.

Figure 1. HVLP spray gun
Source: Spraytech

Airless spray guns

When using airless spray guns, the coating material itself is pressurised. It is then atomised at a spray nozzle without the use of air. Airless spraying is more suited for high application rates.

Figure 2. Airless spray gun
Source: Aircom

Compared to a spraying efficiency of as low as 30 % for conventional spraying operations, HVLP and airless spraying improve spraying efficiency up to 75%. HVLP or airless spraying may not be suitable for all coating materials. This situation is likely to change as low solvent coatings are improved.

Computer-aided spraying

Computer-aided spraying involves automated systems that sense area, either by a mechanical feeler, electric eye, or ultrasonic system, and controls 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.

Computer-aided spraying can prevent up to 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.

Figure 3. Computer-aided spraying
Source: Erretre

Existing equipment can be retrofitted for HVLP, airless and computer-aided spraying, but the costs and effort involved will depend on the type of systems already in place. Proper design and operation of the spraying exhaust is important for reducing pollution and fire risks.

Curtain coating

Curtain coating can be compared to roller coating but cannot be used as a substitute for spray coating. This technique may be used to apply finishes that have a high organic-solvent content.

Roller coating

In roller coating, the finish is applied by grit rollers to the surface of the leather, similar to the process used in printing. Differences exist 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 the cleaning of rollers, to produce the desired quality. It might not be applicable to very thin leathers.

Roller coating techniques are nowadays well established but further research and developments are ongoing. More specialised 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. Forward coating is suitable for lighter top and contrast coats (typically 1-5g/ft^2, 0.09-0.46m^2); reverse coating for heavier impregnation and base coats (3-30g/ft^2, 0.28-2.79m^2).

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. Avoidance of the mist and solid particulate emissions associated with spraying is also beneficial.

This technique is not as flexible as spraying and can be applied only for the production of leathers with a coated grain, not for aniline, aniline-type or semi-aniline leathers.

Figure 4. Roller coater
Source: Gemata

Bio-based finishing

Current leather finishing technologies must be innovated to increase product quality while reducing polluting and hazardous chemicals. Therefore, the leather industry must develop new bio-based systems for finishing, aiming at more environmentally friendly production processes. Developing new bio-based finishing systems with highly compatible base and topcoats, as well as highly compatible finishing formulations and leather surfaces, is the most challenging objective in this field.

In a recent study (Gargano, 2023), collagen, previously enzymatically extracted from leather-tanned wastes, was used as an ingredient for the base and topcoats of leather finishing formulations. Contrary to the studies reported in the literature, the extracted collagen was treated with transglutaminase to cross-link with casein, in order to combine the finishing properties of casein to collagen's binding properties and compatibility with leather. The formulations were first prepared as films to test their properties, and then, sprayed on the leather.

The developed formulations were compared to a standard resin-based finishing formulation, in terms of the physical properties of the leather and the biodegradability of the solutions. They allowed the replacement of recalcitrant polyurethanes and acrylic resins with waste-extracted collagen through its enzymatic crosslinking with casein. Physical softness and colour fastness tests showed that this formulation was proven innovative, eco-sustainable, and capable of conferring the same quality standards to leather as resin-based formulations.

5.2. Approaches for reducing energy consumption

The following are a few strategies and techniques associated with low energy leather finishing:

Water-based finishes

Water-based finishing systems involve using water as a carrier for the finishing agents, reducing the need for VOCs and hazardous solvents. Water-based finishes are generally more environmentally friendly and energy-efficient compared to traditional solvent-based systems.

Ultraviolet (UV) cured finishes

UV-cured finishes involve using UV light to cure or harden the finish on the leather surface. This method eliminates the need for lengthy drying or curing times, reducing energy consumption. UV curing is also associated with reduced emissions of VOCs.

Spray finishing techniques

Utilising advanced spray application techniques, such as electrostatic spraying, can help achieve uniform and efficient coverage with minimal overspray. This not only reduces the amount of finish needed but also minimizes waste and energy consumption.

Drying technologies

Employing energy-efficient drying technologies, such as infrared drying or microwave drying, can significantly reduce the time and energy required to dry the applied finish. These methods allow for quicker curing and reduced energy expenditure compared to traditional heat-based drying methods.

Mechanical and physical processes

Some low-energy finishing techniques rely on mechanical or physical processes, such as embossing or pressing, to create decorative textures or patterns on the leather surface. These methods require less energy compared to chemical-based processes.

Reduced layering

Applying fewer layers of finish or using thinner coatings can help conserve energy by minimising the time required for drying and curing. This approach can also result in a more natural look and feel of the leather.

Integrated process design

Implementing an integrated approach to the entire leather production and finishing process can optimize energy usage and minimize waste. This includes designing processes that are more streamlined and efficient from start to finish.

Recycling and waste reduction

Properly managing waste materials and recycling solvents or other components can contribute to a more sustainable and energy-efficient leather finishing process.

6. CONCLUSIONS

The leather industry is currently between two opposing paths: on the one hand, recent legislative trends in terms of the eco-sustainability of industrial processes are leading leather manufacturing towards the development of cleaner production methods; on the other hand, the spread of new alternative materials to leather is driving the leather industry to improve its competitiveness by developing new innovative and high-quality products.

Leather finishing is one of the most important phases of leather production and is capable of improving its quality and organoleptic properties. However, this phase is characterised by the use of polluting chemical products, such as volatile organic compounds, potentially toxic crosslinking agents, and hardly biodegradable resins, as well as by the use of high energy-consuming processes.

Manufacturers and researchers continually explore new technologies and techniques to minimise the environmental impact of leather production and finishing while maintaining product quality and aesthetics.

7. RECOMMENDATIONS

Tanneries should try to achieve a reduction in the energy consumption of natural gas and electricity by integrating renewable energy sources that can generate thermal and electrical energy. Furthermore, the integration of renewable energy sources is one of the aspects considered in the LWG protocol to promote a sustainable tanning process. Indeed, solar systems represent the most widespread technologies in terms of renewable exploitation, and prices have decreased a lot in recent decades, becoming economically attractive. However, in order to maximise the use of renewables, an on-site storage device should be considered to reduce the mismatch between energy production and demand.

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