Environmental, Health, and Safety Guidelines for Tanning and Leather Finishing

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)[1]. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment. .

Applicability

The EHS Guidelines for Tanning and Leather Finishing include information relevant to tanning and leather finishing projects and facilities, and specifically to operations related to preliminary treatment of the raw hide, tanning processes, post-tanning processes, and finished products manufacturing. Annex A contains a full description of industry activities for this sector**.** Aspects relevant to animal slaughtering are discussed in the EHS Guidelines for Meat Processing. This document is organized according to the following sections:

[1] Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with tanning and leather finishing, which occur during the operational phase, along with recommendations for their management. Recommendations for the management of EHS issues common to most large industrial facilities during the construction and decommissioning phases are provided in the **General EHS Guidelines**.

1.1 Environmental

Environmental issues associated with tanning and leather finishing include the following:[2]

- Wastewater
- Air emissions
- Solid waste
- Hazardous materials

Wastewater

Industrial Process Wastewater

Process water consumption, and consequently wastewater effluent discharges, varies greatly between tanneries, based on the processes involved, raw materials, and products. Generally, water consumption is greatest in the pre-tanning areas, but significant amounts of water are consumed also in the post-tanning processes.

Wastewater from the beamhouse processes (e.g. soaking, fleshing, dehairing, and liming) and from associated rinsing is generally collected together. It may contain hide substance, dirt, blood, or dung and therefore have significant loads of organic matter and suspended solids.

Wastewater from tanyard processes, deliming and bating may contain sulfides, ammonium salts, and calcium salts and is weakly alkaline. After pickling and tanning processes, the main wastewater contaminants depend on the tanning techniques used. Finishing wastewaters may contain lacquer polymers, solvents, color pigments and coagulants.

The potential for increased efficiency through process change is significant and should be clearly identified in the design of the facilities and processes. General wastewater management measures and process optimization in tanning facilities should aim to reduce the need and intensity of end-of-pipe treatment through implementation of wastewater prevention measures, including:

- Reduction of water consumption, through recycling of process streams;
- Use of 'batch" instead of 'running water' washes;
- Segregation of wastewater streams (e.g. soaking liquors, sulfide-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 percent water with respect to normal floats), which allow for water savings of up to 70 percent 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, as specified below;

[2] The quantities and qualities of emissions and waste produced by tanneries strongly depend on the type of leather processed, the source of hides and skins, and the techniques applied. A significant amount and variety of chemicals and proprietary products are used in the processes.

- Split hides before deliming and tanning, when feasible, to allow improved penetration of the tanning chemicals into fiber structure thereby reducing chemical usage.

Additional recommended approaches to reduce generation of specific contaminants in wastewater effluent include the following:

COD/BOD and Suspended Solids

Approximately 75 percent of the organic load (measured as bio-chemical oxygen demand [BOD] and chemical oxygen demand [COD]) is produced in the beamhouse, with the main contribution coming from liming / dehairing processes. Dehairing is also the main generator of total suspended solids. An additional source of COD / BOD is the degreasing process. Total COD/BOD concentrations can reach 200,000 mg/l. Measures to reduce the organic load of these wastewater streams include the following:

- Screen wastewater to remove large solids;
- Use an enzymatic dehairing process and recover hair for resale, reducing COD by up to 40–50 percent);
- If conventional lime dehairing process is used, filter wastewater to recover hair before dissolution. This may reduce COD by 15–20 percent and total nitrogen by 25–30 percent in mixed tannery effluent;
- Recycle liming float which may reduce COD by 30–40 percent; nitrogen by up to 35 percent, sulfide use by up to 40 percent, and lime use by up to 50 percent;
- Use easily degraded ethoxylated fatty alcohols, instead of ethoxylated alkylphenols, as surfactants in degreasing;
- Use carbon dioxide (CO_2) 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.

Salts and Total Dissolved Solids

Salting and other tannery processes contribute to the presence of salts / electrolytes in wastewater streams, measured as Total Dissolved Solids (TDS). Approximately 60 percent of total chloride is produced from salt used for curing, which is subsequently released in the soaking effluent. The rest is generated mainly from pickling and, to a lesser extent, tanning and dyeing processes. Additional contributors to TDS include the use of ammonium chloride and sodium sulfate. The TDS concentrations may reach 15,000 mg/l in tannery effluents. Disposal of waste-neutral electrolyte is a significant challenge for leather manufacturing, particularly for those facilities located in land-locked areas. Measures to reduce TDS loads from raw material preservation and processing include the following:

- Use of natural drying of small skins at facilities in suitable 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 CO_2 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[3];

- 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.[4]
- Recycling of supernatant from chrome recovery to enhance chrome savings;
- Use of liquid dyes and syntans.

Sulfides

Inorganic sulfides (NaHS or Na_2S) and lime treatment are used in the dehairing process, which may result in sulfide-containing liquors in the wastewater effluent. Although a total substitution of sulfides used in this process is not practical, especially for bovine hides, the following approaches are recommended to reduce sulfide use and discharge:

- Use an enzymatic dehairing process;
- For conventional lime dehairing processes, use sulfide and lime in a 20–50 percent overall solution;
- Maintain sulfide-containing wastewater at an alkaline pH (>10) level. The conventional treatment is lime and sulfide wastewater oxidation (catalytic oxidation tanks, or aeration tanks). Care should be taken to avoid an accidental pH value–dependent (pH<7) release of hydrogen sulfide (H_2S), arising from, for example, inappropriate mixing of alkaline and acid streams, and uncontrolled release from denitrification steps.

Nitrogen Compounds

Significant nitrogen loads and resulting discharge of ammonia nitrogen are typically associated with tanning processes. The use of ammonium salts in the process is a main source of ammonia nitrogen in tannery effluents (up to 40 percent). Other sources of ammonia nitrogen are dyeing and animal proteins generated from beamhouse operations. The majority of total nitrogen matter (measured as Total Kjeldahl Nitrogen, TKN) is discharged from the liming process in the beamhouse operations, which, as a whole, account for approximately 85 percent of TKN load from a tanning facility.

Prevention and control measures that reduce the organic load (COD / BOD_5) may also reduce nitrogen levels. Additional measures to reduce the nitrogen load in effluents include:

- Use ammonium-free deliming agents (e.g. weak acids or esters) if CO_2 deliming is not implemented;
- Where ammonia discharge might adversely affect the receiving water, include denitrification in wastewater treatment to convert ammonia nitrogen to nitrates, although careful control and management is needed to limit the potential risk of H_2S formation.

Chromium and Other Tanning Agents

Trivalent chromium salts (Cr III) are among the most commonly used tanning agents, accounting for the majority (approximately 75 percent) of the chromium in the wastewater stream. The remainder is typically generated from post-tanning wet processes, from stock drainage, and wringing. The reducing characteristics of tannery sludge serve to stabilize Cr(III) with

[3] The rate of chromium fixation may be increased using these techniques, and combined with self-basifying chrome compounds and dicarboxylic acid. High-exhaustion tanning may allow the reduction of 80 to 98 per cent of chromium from the liquor, reducing the concentration of chromium in the effluent (4–25 mg / liter). A reduction of chromium discharge in effluent from 5–6 kg chrome per ton hide (using conventional tanning) to 0.2–0.5 kg per ton (using high-exhaustion tanning) may be achieved.

[4] This technique may significantly reduce chromium effluent levels from tanning (up to 20 percent of the chromium used in a conventional tannery process, and up to 50 percent for wool-on sheepskins). Excess chromium containing liquor that cannot be easily recycled may be precipitated and then recycled.

respect to hexavalent chromium (Cr VI) content, as a result of the presence of organic matter and sulfide[5].

The following measures should be taken to limit use and discharge of chromium:

- 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.[6]
- 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 percent in a conventional tannery process, and up to 50 percent in wool-on sheepskins. Liquor containing excess chromium may be precipitated, acidified, and then recycled[7].
- 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, asalkaline conditions and presence of excess oxygen can lead to the conversion of Cr(III) into more toxic Cr(VI).

Post-Tanning Chemicals

Post-tanning operations involve use of several classes of chemicals including fatliquoring agents, chlorinated organic compounds, impregnating agents, sequestering agents, masking agents, and dyes. Impregnating agents are used to improve wearing qualities, achieve oil-repelling or anti-electrostatic properties, reduce permeability to gas, redcue abrasion, and to act as flame retardant. Other complexing agents (e.g. Carboxylic acids, Di-carboxylic acids and their respective salts) are used as masking agents in chrome tanning (certain phthalates, such as di-sodium phthalates (DSP), are also used as masking agents).

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

- 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. ethylen-diamin-tetraacetate);
- Avoid the use of Di-carboxylic acids for the precipitation of chromium during pre-treatment of effluent;

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[5] The International Union of Environment Commission, a part of the International Union of Leather Technologists and Chemists Societies (IULTCS) maintains that, for an integrated tannery, operating from raw hide to wet blue, the lowest practical chromium level is 5000 mg Cr(III) per kg dry solids in the mixed tannery sludge, which is achievable using best available practices and technologies.

[6] Alternative mineral agents may include aluminum, titanium dioxide, and zirconium. Organic tanning agents may include vegetable tanning agents, syntans, resins, polyacrylates, and aldehydes. Vegetable tanning agents generally have low environmental, health and safety risk. Some syntans, resins, polyacrylates, and aldehydes may have low biodegradability and they may include nitrogen or compounds that are toxic to humans or aquatic life, such as formaldehyde, glutaraldehyde, or monomers (e.g. acrylic acid).

[7] Precipitants that may be used typically include sodium carbonate, sodium hydroxide, and magnesium oxide. The addition of polyelectrolyte may improve flocculation. Sludge obtained after sedimentation and filtration may be redissolved in sulfuric acid. In conventional tanning, this recycling process results in a clarified effluent, with typically less than 10 mg/l of chromium (expressed as Cr). The clarified effluent may be reused for pickling, tanning float, or soaking float.

- Avoid the use of zadyes with carcinogenic amines (e.g. diphenil-4amine, benzidine);[8]
- Substitute organic solvent based dyes with non-halogenated and solvent / water-based and water-soluble dyes for dyeing and finishing operations.

Biocides

Biocides are usually included in most liquid chemical formulations such as dyes, fatliquors, and casein finishes. Biocides are potentially toxic and include bactericides and fungicides. Bactericides are used mainly at the beginning of the leather-making process, during the curing and soaking phases. Fungicides are typically used from the pickling stage to the drying stage, because the pH conditions in these processes are ideal for mold growth. In addition, pesticides used in farm animal husbandry (e.g. ectoparasiticides) may also be found in raw hides and skins.

Biocides applied in the tannery industry are essentially non-oxidizing biocides, and are categorized as quaternary ammonium compounds, isothiazoles, thiocarbamates, and others (such as sulfur containing hetero-cycles like derivatives of benzothiazole, for example, 2-(thiocyanatomethylthio)-1,3-benzothiazole [TCMTB] and glutaraldehyde). Fungicides include phenol derivates (ortho-phenylphenol), TCMTB, carbamates, among others. Halogenated organic compounds (e.g. bronopol [2-bromo-2-nitro-propane-1.3-diol]may also be used.

The following measures are recommended to reduce potential impacts of biocides in wastewater:

- Avoid the use of banned chlorinated / halogenated phenols, as well as banned, and less biodegradable, biocides containing arsenic, mercury, and chlorinated substances;[9]
- 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 the **General EHS Guidelines**.

Process Wastewater Treatment

Techniques for treating industrial process wastewater in this sector include source segregation and pretreatment for removal / recovery of chromium; grease traps, skimmers or oil water separators for separation of floatable solids; filtration for separation of filterable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; biological treatment, typically aerobic treatment, for reduction of soluble organic matter (BOD); biological nutrient removal for reduction in nitrogen and phosphorus; chlorination of effluent when disinfection is required; dewatering and disposal of residuals in designated hazardous waste landfills. Additional engineering controls may be required for (i) advanced metals removal using membrane filtration or other physical/chemical treatment technologies, (ii) reduction in effluent toxicity using appropriate technology (such as reverse osmosis, ion exchange, activated carbon, etc.), (iii) reduction in TDS in the effluent using reverse osmosis or evaporation, and (iv) containment and neutralization of nuisance odors.

Management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. Through use of these technologies and good practice techniques for wastewater management, facilities should meet the Guideline Values for wastewater discharge as

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[8] Directive of the European Parliament and of the Council amending Council Directive 76/769/EEC

[9] In accordance with the Stockholm Convention on Persistent Organic Pollutants

indicated in the relevant table of Section 2 of this industry sector document.

Other Wastewater Streams & Water Consumption

Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the **General EHS Guidelines**. Contaminated streams should be routed to the treatment system for industrial process wastewater. Recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**.

Air Emissions

Air emissions from tanning facilities include organic solvents from tanning and leather finishing operations; sulfides from the beamhouse and wastewater treatment; ammonia from the beamhouse, tanning, and post-tanning operations; dust / total particulate from various process operations; and odors. Emissions of sulfur dioxide may occur during bleaching, post-tanning operations, or CO_2 deliming, but they are not typically a significant source of emissions.

Organic Solvents

Organic solvents are used in degreasing and finishing processes. Untreated organic solvent emissions from the finishing process may vary between 800 and 3,500 mg/m^3 in conventional processes. Approximately 50 percent of VOC emissions arise from spray-finishing machines, and the remaining 50 percent from dryers. Chlorinated organic compounds may be used and emissions released from soaking, degreasing, dyeing, fatliquoring, and finishing processes.

Pollution prevention and control measures include the following:

- 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 economizers and high-volume / low-pressure spray guns;
- Prohibit the use of internationally banned solvents;[10]
- Control VOC emissions through the application of secondary control techniques as described in the **General EHS Guidelines**. Examples of industry-specific controls include wet scrubbers (including the use of an oxidizing agent to oxidize formaldehyde), activated carbon adsorption, biofilters (to remove odors), cryogenic treatment, and catalytic or thermal oxidation.

Sulfides

Sulfides are used in the dehairing process. Hydrogen sulfide (H_2S) may be released when sulfide-containing liquors are acidified and during normal operational activities(e.g.opening of drums during the deliming process, cleaning operations / sludge removal in gullies and pits, and bulk deliveries of acid or chrome liquors pumped into containers with solutions of sodium sulfide). H_2S is an irritant and asphyxiant.

Prevention and control measures for sulfide emissions include the following:

- Maintain a basic pH over 10 in facility equalizing tanks and sulfide oxidation tanks;
- Prevent anaerobic conditions in sulfate-containing liquors and sludge;

[10] Refer to the list of solvents banned under the Montreal Protocol on Ozone Depleting Substances. The schedule for phase-out of particular solvents may be established by host-country regulations.

- Add manganese sulfate to treated effluent, as needed, to facilitate the oxidation of sulfides;
- Where H_2S formation may occur, use adequate ventilation to capture the emissions, followed by treatment with wet scrubbers or biofilters (particularly for wastewater treatment units).

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 coloring process). Prevention and control of ammonia emissions may be achieved through use of adequate ventilation , followed by wet scrubbing with an acidic solution.

Dust

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 use of a centralized system, employing cyclones, scrubbers, and / or bag filters, as needed.

Odors

Odors may result from raw hides and skins, putrefaction, and from substances including sulfides, mercaptans, and organic solvents. Prevention and control measures for odor emissions include the following:

- 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 percent solids may generate especially strong odors;
- Ventilate tannery areas and control exhaust from odorous areas (e.g. where wastewater sludge is thickened and dewatered), through use of a biofilter and / or a wet scrubber with acid, alkali, or oxidant.

Solid Waste

Solid waste includes salt from raw skin / hide dusting; raw skin / hide trimmings; hair from the liming / dehairing process, which may contain lime and sulfides; and fleshing from raw skins / hides. Other solid waste includes wet-blue shavings, which contains chromium oxide (Cr_2O_3); wet-blue trimming, which is generated from finishing processes and contains chromium oxide, syntans, and dye; and buffing dust, which also contains chromium oxide, syntans, and dye. The reducing characteristics of tannery sludge stabilize Cr(III) with respect to Cr(VI), due to the presence of organic matter and sulfides.

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 fiberboard);
- 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;[11]

[11] Reference should be made to host-country requirements for limits of hazardous substances in agricultural sludge.

- Dispose of non-recoverable and non-recyclable waste and sludge by appropriate methods, depending on the waste hazard classification, as described in the **General EHS Guidelines**.[12]

Hazardous Materials

Tanning and leather finishing processes involve the use of a variety of hazardous chemicals. Guidance on the management of hazardous materials, including handling, storage, and transportation, is provided in the **General EHS Guidelines.**

1.2 Occupational Health and Safety

Occupational health and safety issues associated with the construction and decommissioning of tanning and leather finishing facilities are common to those of most large facilities and are addressed in the **General EHS Guidelines**. Specific occupational health and safety issues associated with the operation of tanning and leather finishing facilities primarily include the following:

- Exposure to chemicals;
- Exposure to biological hazards.

Chemical Hazards

Tannery workers may be exposed to chemical hazards during loading, unloading, handling, and mixing of chemicals; during the washing, and disposing of chemical containers; and during the management and disposal of chemical waste and effluent. Hazardous chemicals should be managed according to the guidance in the **General EHS Guidelines**. Additional recommendations applicable to tanning and leather finishing facilities include the following:

- Replace organic solvent-based chemicals with water-based chemicals in degreasing and finishing processes;
- Limit exposure to hazardous chemicals by promoting chemical handling procedures, and dosing and transferring chemicals in fully or partly closed systems using automated systems;
- Implement management procedures and controls for discharge of floats from paddles and drums;
- Use equipment and techniques (e.g. roller coating) to minimize indoor air pollution (e.g. during spraying and general application of finishing treatments);
- Use air extraction systems and ventilation in areas / machines for dry shaving, buffing, dedusting, spraying, and weighing (e.g. chemicals);
- Use of personal protection equipment (e.g. gloves, glasses boots, aprons, masks, hoods, respirators), particularly in the wet activity areas of the tannery. Respirators / masks with particulate filters and glasses should be used when handling powder and liquid chemicals

Chemical Storage and Handling

In addition to the hazardous materials management measures discussed in the **General EHS Guidelines**, the following measures should be employed for tanning and leather finishing facilities:

- Chemicals that will react should be segregated. Specifically, acids should be stored away from sodium sulfide, and alkalis away from ammonium salts, to prevent accidental mixing and release of dangerous gases (e.g. H_2S, NH_3);

[12] Incineration should be conducted only according to industry good practice for temperature, residence time, and other necessary conditions to avoid emissions of toxic substances (e.g. chrome (VI), dioxins / furans)

- Pipes, valves, and other equipment should be designed to prevent incorrect addition or mixing of incompatible chemicals (e.g. from a tanker into the wrong storage tank, particularly for acid into a sulfide solution);
- Small containers (e.g. dyes and fatliquors samples) should be safely stored on racks and shelves. Heavier chemical containers (particularly those containing liquid chemicals, such as acids) should be stored on wooden or plastic pallets at the floor level;
- Chemicals should be distributed from a gangway located over the beamhouse, and the tanning / post-tanning drums. The gangway should be equipped with adapted tanks connected to the drum axle.

Biological Hazards

Workers may be exposed to disease-agents such as bacteria, fungi, mites, and parasites which may be present in the hides or as part of the manufacturing process. Management measures that can be taken to avoid the negative consequences of worker exposure to biological hazards include the following:

- Inform workers of potential risks of exposure to biological agents and provide training in recognizing 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.

Additional guidance on prevention and control of biological hazards is presented in the **General EHS Guidelines.**

1.3 Community Health and Safety

Community health and safety impacts during the operation of tanning and leather finishing are common to those of most industrial facilities, and are discussed in the **General EHS Guidelines**. These impacts include, among others, traffic and hazardous materials safety from raw material delivery and from finished product shipments.

While odors from leather tanning are not generally hazardous, they can constitute a nuisance to the surrounding community. In addition to the prevention and control of odor emissions previously described, greenfield projects should consider the location and distance of a proposed facility with regards to residential or other community areas.

2.0 Performance Indicators and Monitoring

2.1 Environment

Effluent and Emission Guidelines

Table 1 presents effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document. These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

Combustion source emissions guidelines associated with steam- and power-generation activities from sources with a heat input capacity equal to or lower than 50 MWth are addressed in the **General EHS Guidelines** with larger power source emissions addressed in the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the **General EHS Guidelines**.

Table 1. Effluent Levels for Tanning and Leather Finishing

Pollutants	Units	Guideline Values
pH	S.U.	6-9
BOD_5	mg/L	50
COD	mg/L	250
Total Suspended solids	mg/L	50
Sulfide	mg/L	1.0
Chromium (hexavalent)	mg/L	0.1
Chromium (total)	mg/L	0.5
Chloride	mg/L	1000
Sulfate	mg/L	300
Ammonia	mg/L	10
Oil and Grease	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	°C	<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

Table 2. Air emission levels for leather finishing	
Pollutants	**(kg of HAP loss per 100 sq. meters of leather processed)**
Upholstery Leather (= 4 grams add-on/square feet)	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.

Resource Use

The following Tables 2 through 7 provide examples of resource consumption and waste generation benchmarks in this sector. Industry benchmark values are provided for comparative purposes only and individual projects should target continual improvement in these areas.

Table 3. Effluent Loads from Tannery Processes [abc]

Values per tonne of rawhide	Water (m^3/t)	COD (kg/t)	BOD_5 (kg/t)	SS (kg/t)	Cr(III) (kg/t)	Sulfides (kg/t)
Bovine Salted Raw Hide Process[d]	12–50	145–230	48–86	85–155	3–7	2–9
Pig Skins	32–69	140–320	52–115	70–135	3–6	3–7
Sheepskins (wet-salted)	110–265	330–1005	135–397	175–352	9–15	6–20
Wool-on Sheepskins	360	780	220	195	20	—

Notes:
[a] Typical pollution loads under good practice conditions. They include pollution loads from beamhouse, tanning operations, post-tanning and dyeing operations, finishing.
[b] All values indicated relate to processing under good practice conditions. IUE reports that the ranges reflect variations in raw materials and processes.
[c] Taking into account the increasing importance of water conservation, the IUE indicates that this practice leads to higher pollution level in terms of concentration. For this reason, the IUE commission has requested that the regulating authorities limit discharges in terms of mass rather than concentration.
[d] Goat skins generate similar loads to bovine hides
Sources: IUE (2004); EC IPPC (2001)

Table 4. Effluent Loads from Tannery Processes [abc] (continued)					
Values per tonne of rawhide	**TKN (kg/t)**	**Chlorides (kg/t)**	**SO_4 (kg/t)**	**Oil/Grease (kg/t)**	**TDS (kg/t)**
Bovine Salted Raw Hide Process [d]	10–17	145–220	45–110	9–18	300–520
Pig Skins	12–20	80–240	40–100	34–71	180–500
Sheepskins (wet-salted)	21–44	210–640	45–110	40–150	—
Wool-on Sheepskins	21	910	--	40–150	1520

Notes:
[a] Typical pollution loads under good practice conditions. They include pollution loads from beamhouse, tanning operations, post-tanning and dyeing operations, finishing.
[b] All values indicated relate to processing under conditions of good practice. IUE reports that the ranges reflect variations in raw materials and processes.
[c] Taking into account the increasing importance of water conservation, the IUE indicated that this practice leads to higher pollution level in terms of concentration. For this reason, the IUE commission has requested that the regulating authorities limit discharges in terms of mass rather than concentration.
[d] Goat skins generate similar loads to bovine hides
Sources: IUE (2004); EC IPPC (2001)

Table 5. Dry Sludge Generation from Tannery Wastewater Treatment	
Parameters	**Sludge Production kg DS/tonne rawhide**
Sludge (total)	200 [a]
Primary Treatment	
Mixing + Sedimentation	80
Mixing + Chemical treatment + Sedimentation	150–200
Mixing + Chemical treatment + Flotation	150–200
Biological Treatment	
Primary or chemical + Extended aeration	70–150 [b]
Primary or chemical + Extended aeration with nitrification and denitrification	130–150 [b]
Primary or chemical + Aerated facultative lagoons	100–140
Anaerobic treatment (lagoon or UASB) [c]	60–100
Membrane biological reactor (MBR)	d

Notes:
[a] 500 kg (approx. 40 percent dry matter content)
[b] Without chemical treatment
[c] Mixed with 75% domestic sewage, UASB = upflow anaerobic sludge blanket
[d] Approximately 7% of the metabolized COD is incorporated into surplus sludge production, compared to 30–50% in a conventional activated sludge system
Source: IUE (2004), EC IPPC (2001)

Table 6. Solid Waste Generation		
Output per unit of product	**Mass Load Unit**	**Industry Benchmark**
Solid Waste (Hazardous / Non-Hazardous) (bovine salted hides, conventional chrome-tanning)	kg/tonne	450–730
Air Emission (organic solvents) (bovine salted hides, conventional chrome-tanning)	kg/tonne	Approx. 40

Source: EC IPPC (2001)

Table 7. Resource and Energy Consumption		
Inputs per unit of product	**Mass Load Unit**	**Industry Benchmark**
Energy/ Fuel Energy consumption per unit of production (bovine salted hides, conventional chrome-tanning)	GJ/tonne	9.3–42
Materials Chemical consumption (bovine salted hides, conventional chrome-tanning)	kg/tonne	Approx. 500

Source: EC IPPC (2001)

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®) published by American Conference of Governmental Industrial Hygienists (ACGIH),[13] the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),[14] Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),[15] Indicative Occupational Exposure Limit Values published by European Union member states,[16] or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)17.

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals[18] as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

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[13] Available at: http://www.acgih.org/TLV/ and http://www.acgih.org/store/
[14] Available at: http://www.cdc.gov/niosh/npg/
[15] Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992
[16] Available at: http://europe.osha.eu.int/good_practice/risks/ds/oel/
[17] Available at: http://www.bls.gov/iif/ and http://www.hse.gov.uk/statistics/index.htm
[18] Accredited professionals may include Certified Industrial Hygienists, Registered Occupational Hygienists, or Certified Safety Professionals or their equivalent.

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Annex A: General Description of Industry Activities:

Tanning and leather finishing facilities generally convert raw hides and / or skins into leather, which is then finished and used to manufacture a wide range of products. Tanning is the process used to stabilizing the raw hide or skin into leather, a non-putrescible product.

This guideline focuses on processing of bovine and ovine hides and skins. In general, the production processes in a tannery can be split into four main stages including hide and skin storage, and operations involving the beamhouse , tanning, post-tanning, and finishing.

Hide and Skin Prestorage / Storage, and Beamhouse Operations

Raw hides and skins are typically procured from the hide and skin markets or directly from the abattoirs (slaughterhouses), and delivered to the tanneries or fellmongeries (facilities that treat skins and hides, principally sheep skins, before tanning). Hide and skin curing is often performed before transport to the tannery / fellmongery, as necessary, to prevent putrefaction. At the tannery / fellmongery, hides and skins are preliminary sorted, trimmed, cured, and stored.

Sorting and Trimming

Sorting of hides and skins is conducted according to several grades of size, weight, quality and sex. Trimming is generally carried out during the sorting process.

Curing and Storing

If the raw hides and skins cannot be processed immediately, they are typically cured to prevent putrefaction. Curing methods for long-term preservation (up to six months) include salting, brining, (shade) drying, or dry salting. Short-term preservation (typically two to five days) involves cooling using crushed ice, or refrigerated storage, in addition to biocides / antiseptics / fungicides (e.g.2-[thiocyanatomethylthio]-1,3-benzothiazole known as TCMTB, isothiazolones, potassium dimethyl dithiocarbamate, sodium chlorite benzalkonium chloride, sodium fluoride, and boric acid). Some of these agents are also used during soaking, pickling, and wet-blue preservation.

Although curing is often conducted in the abattoir or at the hide market, the process may be repeated in the tannery for longer and more efficient storage. Hides and skins are generally stored on pallets in ventilated or air conditioned / cooled areas. From storage, the hides and skins are taken to the beamhouse. Processes typically carried out in the beamhouse of a tannery include soaking, dehairing, liming, and fleshing, whereas fellmongeries typically carry out similar processes specific to sheep skins.

Soaking

Soaking is undertaken to allow hides and skins to reabsorb any lost water after flaying, as well as to clean and remove interfibrillary material. Soaking is usually carried out in processing vessels (e.g. mixers, drums, pits, or raceways) in two steps, namely a dirt soak for salt and dirt removal, and a main soak. The soak bath is often changed every 8 hours to prevent bacterial growth. Soaking additives include surfactants, enzyme preparations, bactericides, and alkali products.

Dehairing and Liming of Bovine Hides

Dehairing and liming of hides is undertaken to remove hair, interfibrillary components, and epidermis, and to open up the fiber structure. These processes are carried out in vessels (e.g. drums, paddles [a vat with a paddlewheel agitator], mixers, or pits). Dehairing involves the use of chemical and mechanical treatment, with or without hair destruction. Elimination of keratinous material (e.g. hair, hair roots, epidermis) and fats from the pelts involves the use of inorganic sulfides (NaHS or Na_2S) and lime treatment. Treatment with organic compounds such as mercaptans or sodium thioglycolate in combination with strong alkali and amino compounds is an alternative to sulfide treatment. Enzymatic preparations can be added to enhance dehairing and they are considered a cleaner technology when compared with the conventional dehairing-liming process.

Painting and Liming of Sheepskins

Painting is undertaken to break down the wool root within the sheepskins to facilitate pulling of wool fiber from the pelt. Paint generally consists of a highly viscous mixture of sodium sulfide and lime, applied to the flesh side of the skin either through a spraying machine or manually and left for several hours. The wool is then pulled from the skin, either manually or mechanically. After pulling, the skins are limed in process vessels, similarly to bovine hides.

Fleshing

Fleshing is a mechanical process to scrape off the excess organic material from the hide (e.g. connective tissue and fat). The fleshing machine consists of rollers and rotating spiral blades that treat the pelts. Fleshing of green hides after soaking is called 'green-fleshing'. Fleshing performed after the liming and dehairing is known as 'lime-fleshing'.

Tanyard Operations

Tanyard operations transform cured hides into leather, and typically include deliming, bating, degreasing, pickling, pretanning, tanning, draining /samming / setting, splitting, and shaving. Deliming, bating, and pickling may also be conducted at fellmongeries, which sell pickled skins as an intermediate product.

Deliming

Deliming involves the removal of residual lime from the pelts and preparing the pelts for bating. The conventional process involves gradually lowering pH through washing and addition of deliming chemicals (e.g. ammonium sulfate [$(NH_4)_2SO_4$], ammonium chloride [NH_4Cl], sodium bisulfite [$NaHSO_3$], among others); an increase in temperature; and, finally, the removal of residual chemicals and degraded skin components.

Alternative processes include carbon dioxide (CO_2) deliming, or the use of ammonium-free deliming agents (e.g. weak acids or esters) which can totally or partially replace ammonium salts used for conventional deliming. For thicker pelts, the float temperature is increased (up to 35°C), the process duration is increased, and small amounts of deliming auxiliaries are added. Generally, deliming is performed in processing vessels (e.g.drums, mixers, or paddles).

Bating

Bating allows a partial degradation of non-collagenic proteins, achieved by enzymatic preparations, and improves the grain of the hide and the subsequent run and stretch of the leather. Scud (e.g. hair roots and other unwanted material) is also removed at this stage. The quantity of enzymes used is the principal factor in determining the final characteristics of the leather in terms of hardness (e.g. lower enzyme concentrations needed) or softness (e.g. higher enzyme concentration needed) of the finished products.

Degreasing

Degreasing eliminates excess grease from fatty skins (e.g. from sheep and pigs) to prevent the formation of insoluble chrome-soaps or fat spues (white fatty material on the leather surface) at a later stage. Skin fat is difficult to remove because of the presence of cerides and the need for a high melting temperature. Three different methods commonly used for degreasing include degreasing in aqueous medium with nonionic surfactant and degreasing agents; degreasing in aqueous medium with organic solvents, nonionic surfactants, and degreasing agents; and degreasing in an organic solvent medium.

The solvent used for degreasing (e.g. paraffin, white spirit, butyl oxitol, ethyl oxitol, TCE, PCE, mono-chloro-benzene and per-chloro-benzene) can be partially recovered, the extraction brines recycled, and the natural grease recovered for commercial use. The amount of surfactant required decreases with the increased use of organic solvents.

Pickling

Pickling is conducted to lower the pH of the pelt before mineral tanning and some organic tanning (e.g. chrome tanning, gluterdialdehyde tanning, vegetable tanning, resins and synthetic tanning). Very often tanning is carried out in the pickle liquor. Pickled pelts can be traded and contain fungicides to protect them from mold growth during storage. Pickling floats (the aqueous liquor in which the pickling process is performed) are typically characterized by high salt concentrations, which can be reduced by using acids that lessen the water uptake of the skins (e.g. non-swelling acids, typically aromatic sulfonic acids).

Wet-White Pretanning

Pretanning processes change the physical and chemical characteristics of the leather, improving the leather quality, particularly with regard to grain tightness, and chrome uptake, thus reducing the input of chrome. Pretanning agents include aluminum salts, aluminum combined with polyacrylates, glutaraldehyde derivatives, syntans (synthetic tannins typically made by treating aromatic substances, such as cresols, phenols, and naphthalenes, with formaldehyde and sulfuric acid), titanium oxide and salts, or colloidal silica. Zirconium is an effective agent used to obtain white leather.

Some pretanning agents can significantly raise the shrinkage temperature of the collagen. Pretanned leather can be split and shaved, thus avoiding chrome shaving activities and further reducing the chrome input needed for leather production. Certain pretanning recipes may be combined with nonchromium tanning agents to produce chromium-free leather. However, chrome-free pretanning may not be applicable if the chrome tanning effects are desired in the final leather product, or when the pretanning effects result in an unacceptable coloration of the leather.

Tanning

Tanning allows stabilization of the collagen fiber through a cross-linking action. The tanned hides and skins are tradable intermediate products (wet-blue). Tanning agents can be categorized in three main groups namely mineral (chrome) tanning agents; vegetable tanning agents; and alternative tanning agents (e.g. syntans, aldehydes, and oil tanning agents). About 90 percent of leathers are tanned with salts of chromium (in its trivalent form), especially chromium (III) sulfate.

The vegetable tanning process is not an alternative to the chrome tanning process, as the two processes produce different products. Vegetable tanning produces relatively dense, pale brown leather that tends to darken on exposure to natural light. Vegetable tanning is frequently used to produce sole leather, belts, and other leather goods. Unless specifically treated, however, vegetable tanned leathers have low hydrothermal stability, limited water resistance, and are hydrophilic. Recovery of vegetable tanning floats is generally conducted using ultrafiltration.

Tanning with organic tanning agents, using polymers or condensed plant polyphenols with aldehydic cross-linkers, can produce mineral-free leather with high hydrothermal stability similar to chrome-tanned leather. However, organic-tanned leather usually is more filled (e.g. leather with interstices filled with a filler material) and hydrophilic than chrome-tanned leather. Semi-metal tanning may also produce chrome-free leather, with equally high hydrothermal stability. This tanning process is carried out with a combination of metal salts, preferably but not exclusively aluminum (III), and a plant polyphenol containing pyrogallol groups, often in the form of hydrolysable tannins.

Draining, Samming, and Setting

After tanning, leathers are drained, rinsed, and either hung up to age or unloaded into boxes and subsequently sammed (e.g. brought to a uniformly semi-dry state, (approximately 50% to 60% water content, necessary for certain finishing operations, by passing it through the sammying machine or by pressing between pressurized rollers) to reduce the moisture content before further mechanical action. Setting (working over the grain surface of wet leather to remove excess water, to eliminate wrinkles and granulations, to give the leather a good pattern and to work out stresses so that the leather lies flat) may be carried out to stretch out the leather.

Splitting

The function of the splitting operation is to cut through skins / hides or leathers at a set thickness. If the hide / skin is sufficiently thick, splitting can yield a grain split and a flesh split that may both be processed into finished leather. Although splitting can be performed before tanning, after tanning, or after drying, it is usually performed after tanning.

Shaving

Shaving is undertaken to achieve an even thickness throughout tanned or crusted leather. Shaving is carried out when splitting is not possible or when minor adjustments to the thickness are required.

Post-Tanning Operations

Post-tanning operations involve neutralization and bleaching, followed by retanning, dyeing, and fatliquoring. These processes are mostly undertaken in a single processing vessel. Specialized operations may also be performed to add certain properties to the leather product (e.g. water repellence or resistance, oleophobicity, gas permeability, flame retardancy, abrasion resistance, and anti-electrostatic properties).

Neutralization

Neutralization is the process by which the tanned hides are brought to a pH suitable for retanning, dyeing, and fatliquoring. Neutralization is performed using weak alkalis (e.g. sodium or ammonium bicarbonate, formiate, or acetate). After neutralization, leather may be dried, generating an intermediate tradable product called white crust.

Bleaching

Vegetable-tanned skins and leathers with wool or hair may need to be bleached to remove stains or to reduce the coloring before retanning and dyeing. Making the leather color fade may be achieved using treatment with chemicals (e.g. bleaching agents) or exposure to the sun / weather elements.

Retanning

The retanning process is performed to improve the leather characteristics and the re-wetting properties (e.g. the introduction of liquid, such as water, into hides, skins or dried leather) of the hides necessary to facilitate and optimize the subsequent dyeing process. A wide variety of chemicals may be used for the re-tannage of leather, including vegetable tanning extracts, syntans, aldehydes, resins, and mineral tanning agents.

Dyeing

Dyeing is performed to produce colors in hides / skins. Typical dyestuffs include water-based acid dyes. Basic and reactive dyes are less commonly used. A wide range of dyestuff is available with different characteristics and physico-chemical resistances (e.g. to light, PVC migration, sweat migration, among others).

Fatliquoring

Fatliquoring is the process by which leathers are lubricated to achieve product-specific characteristics and to reestablish the fat content lost in the previous procedures. The oils used may be of animal or vegetable origin, or may be synthetic products based on mineral oils. Stuffing is an old technique used mainly for heavier vegetable-tanned leather. Sammed leathers are treated in a drum with a mixture of molten fat. The retanned, dyed, and fatliquored leathers are then acidified by formic acid for fixation and usually washed before being aged to allow the fat to migrate from the surface to the inside of the pelt.

Drying

The objective of drying is to dry the leather while optimizing leather quality. Drying techniques include samming, setting, centrifuging, hang drying, vacuum drying, toggle drying (leather dried while held under tension on frames using toggles), paste drying (drying method used for upper leather with corrected grain), and over drying. Samming and setting are used to reduce the moisture content mechanically before implementing another drying technique. After drying, the leather may be referred to as ‘crust’, which is a tradable and storable intermediate product.

Finishing Operations

Finishing operations enhance the appearance of the leather and provide the performance characteristics expected in the finished leather with respect to color, gloss, feel, flex, and adhesion as well as other properties including stretch-ability , break, light- and perspiration fastness, water vapor permeability, and water resistance. Finishing operations can be divided into mechanical finishing processes and surface coat applications.

Mechanical Finishing Processes

A wide range of mechanical finishing operations may be performed to improve the appearance and the feel of the leather. The following list of operations includes commonly used mechanical finishing operations, although the list is not exhaustive and many other operations exist for special leathers:

- Conditioning (optimizing the moisture content in leathers for subsequent operations);

- Staking (softening and stretching the leather);
- Buffing / dedusting (abrading the leather surface and removing the resulting dust from the leather surface);
- Dry milling (mechanical softening);
- Polishing;
- Plating / embossing (flattening or printing a pattern into the leather).

These operations may be conducted before, after, or in-between the application of coatings.

Surface Coat Application

A wide range of surface coat application methods exist, including the following:

- Padding or brushing the finishing mix onto the leather surface;
- Spray coating, which involves spraying the finishing material with pressurized air in spray cabinets;
- Curtain coating, which involves passing the leather through a curtain of finishing material;
- Roller coating, which involves the application of finishing mix through a roller;
- Transfer coating, which involves the transfer of a film / foil onto leather previously treated with an adhesive.

Finishing products include polyurethanes, acrylic-based chemicals, silicon, oily and waxy compounds, among others.