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D4.2.3 Performance improvements for the tanning industry

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Audience

This document is targeted at researchers, policy makers, tannery communities, environmental authorities and all the actors that can be part of the decision making scenarios related to the tanning industry.

Purpose

The goal of this research was to create an integrated and optimal solution to the environmental and economic problems of the micro and small tanneries, tailored to fit the conditions and the context of the region of Villapinzon and Choconta in Colombia.

The research objective is to reduce/eliminate emissions to the environment from the tanning production activities, by implementing process and procedural improvements in the production process.

Background

The valley of the Bogotá river is home to almost 20% of Colombia's total population and generates approximately 26% of all national economic activity (DNP, 2004). Water quality indicators for the Bogotá River show a good condition at its source, but a continuous deterioration downstream from there as discharges are received from human settlements and from industrial activities (e.g. BOD: 70 g/m^3, TSS: 100 g/m^3). The degradation of water quality is the result of organic, inorganic and bacteriological pollution from domestic waste water and industrial production activities and has a strong downstream influence on a large fraction of Colombia's territory. This is the reason why establishing an adequate water management system in the zone was defined as a national priority (CONPES[1] 3320, 2004).

The tanning industries in the towns of Villapinzon and Choconta in the upper basin of the Bogotá River have a special importance for the Colombian society. These have been the subject of a variety of studies (Ojeda, 2004) because of their pollution impact on the Bogotá river with industrial wastewater and the resulting conflicts.

The conversion of skins to leather has had, for decades, a highly negative environmental impact. This can be attributed to the obsolete technology used and to lack of awareness of those involved. This results in the spillage of huge volumes of water and chemicals. The resulting solid and liquid wastes were subsequently dumped in the open or discharged into the Bogotá River without any treatment.

[1] Consejo Nacional de Política Económica y Social, Conpes. The highest national planning organ, it serves as an advisor for the Colombian government in every subject of national economic and social development.

A process of environmental conflict resolution was initiated by UNESCO-IHE in 2004. After defining the problem together with the tanning community, Cleaner Production (CP) was chosen and implemented for the resolution of the technological problems (Sanz, 2007). Cleaner Production (CP), within the context of sustainable water management, is considered an integral preventive strategy to improve the environmental, productive, socioeconomic and institutional characteristics of micro and small tanneries. This strategy focuses on achieving eco-efficiency of the tanning activities by anticipating, reducing, or preventing their polluting emissions. A multi-stakeholder support process resulted.

Potential Impact

The improvement process in the tanneries should reduce several parameter values such as organic load, TSS, sulfides, chromium, ammonia nitrogen, chlorides, water consumption and wastewater. The cleaner technological options, searched for in national and international sources, are expected to improve the water quality parameters in significant percentages, *eg.* BOD: 30 – 40%; COD, TSS, Sulfide: 60 – 70%; Total nitrogen: 70 – 80%; Total chromium, chlorides: 80 – 90%). With respect to water consumption and wastewater generation, reductions are expected to vary between 65% and 75%. When extrapolating the impact reduction estimates to all tanneries in the region, the volumes of water not to be consumed and wastewater not to be discharged is estimated to approach 54,000 m^3 per month. Similarly, the energy not consumed approaches 12,000 KWh per month.

Moreover, in terms of the social impacts three variables are taken into consideration: Educational level will increase and ensure that operators and owners in tanneries better grasp relevant information to produce fine quality leather. Social perception is expressed as the overcoming of mental barriers, changing traditional uses, and establishing public opinion and group (community and institutions). By improving their environmental performance, the public opinion of tanneries will improve and regulatory bodies will be more willing to hear them. Finally, there will be an improvement in the life quality for the tanners. By improving their products, processes and environment, they will have better business opportunities, job security and living standard improvement.

CP is expected to be included in environmental regulations as an integrated strategy, in a way that motivates compliance with environmental improvement norms. Through CP implementation it is expected that micro and small tanneries will be legally established as formal companies, with full regulatory compliance and ending legal procedures currently running. This will improve their competitiveness by means of better product quality and access to new markets.

Recommendations

- The tanners must be committed with the improvement process and the recommended approach is a systematic one to reduce and prevent pollution and to use adequately the human, technical and environmental resources.
- To assure a good implementation of new and advanced technologies, best operational practices and basic process improvements must be considered before as the basis of the implementations.
- Technical and technological solutions oriented to obtain better environmental quality, must be jointly worked out with action in association and institutional relationships
- The wastes must be integrated to the leather productive chain to give it value and to generate profit for the industry in an associative way.
- CP implementation requires that the tanners become owners of the process of change. For this reason, it is recommended to speed up and to strengthen the interinstitutional work and make the CP part of the decision making process.
- The regulatory frame cannot be a constraint on the improvement process. The approach must switch from the sanction-oriented one currently in use, to one of continuously “walking with” industries, as well as giving CP a normative frame, going beyond a willingness agreement.

D4.2.3-a Process analytical description for industrial emissions options including material and energy flow balance.
D4.2.3-b Literature overview of feasible modifications for industrial emissions options D4.2.3-c Environmental, social, and economical benefits of the implementation of the feasible process modification

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D 4.2.3 Performance improvements for the tanning industry

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1. Introduction

The tanning industry in the towns of Villapinzon and Choconta has a special importance for Colombian society and has been the subject of a variety of studies due to its location along a 6 km strip of the upper basin of the Bogotá River (Ojeda, 2004). The river's valley is home to almost 20% of Colombia's total population and in this region generates approximately 26% of all national economic activity (DNP, 2004).

Water quality indicators for the Bogotá River show a good condition at its source, but a continuous degradation as discharges are received from human settlements and from industrial activities (e.g. BOD: 70 g/m^3, TSS: 100 g/m^3). These values are well above the goals to be attained by 2020, which are < 7 g/m^3 for BOD and < 10 g/m^3 for TSS, as established by the regional environmental authority Corporación Autónoma Regional (CAR) (Acuerdo CAR 043/ 2006).

The degradation of water quality is the result of organic, inorganic and bacteriological pollution from domestic waste water and industrial production activities, including tanneries, and has a strong downstream influence on a large fraction of Colombia's territory. This is the reason why establishing an adequate water management system in the zone was defined as a national priority (CONPES[1] 3320, 2004).

Tanneries of the study region, Villapinzon and Choconta, are located in a narrow, flat zone, covering nearly 107 hectares including the river bed, a highway and a railroad. Some industrial buildings are inside the exclusion zone, a 30 m zone defined on each side of the river in which no construction is permitted by law.

The conversion of skin to leather has had, for decades, a highly negative environmental impact. This can be attributed to the poor conversion process that uses huge volumes of water and chemicals. The resulting solid and liquid wastes were subsequently dumped in the open, respectively discharged into the Bogotá River without any treatment.

Tanneries in the region follow a long-established tradition. Several generations have usually been involved in the same industry, applying production methods transmitted from their elders. Tanning is the source of family income but as the production volume in most cases is low, so is the income. The educational level just reaches elementary school grade, for owners and operators alike. In terms of training on tanning with natural tanning agents, they received it by word of mouth from previous workers. In recent decades, the process was changed and now it is based on chemicals. This change was made with CAR's recommendation but without adequate training or follow-up (Sanz, 2007a).

[1] Consejo Nacional de Política Económica y Social, Conpes. The highest national planning organ, it serves as an advisor for the Colombian government in every subject of national economic and social development.

The regional economy is characterized as being at a subsistence level, and tanning technology is obsolete. Most of the factories are family businesses and employ from 4 to 6 workers. These family owned factories are the source of employment for 60% of the labor force in the zone, generating around 700 direct jobs. The figure increases to 4,000 by including indirect related jobs (Sanz, 2007a).

As workshops are mostly informal, no study or institution to date has defined the total number of production units currently in operation. In recent work roundtables (September 2009), the accepted figures are 87 tanneries in operation, and 120 if one includes those informally established. However, CAR in 2008 registered 173 workshops. Previously, in 2007, CAR published a list of 105 tanneries arranged according to their production capacity.

Since 2004, the Cámara de Comercio de Bogotá (CCB), Ministerio de Ambiente, Vivienda y Desarrollo Territorial (MAVDT), Gobernación de Cundinamarca, CAR, Colciencias, UNESCO-IHE Institute for Water Education (The Netherlands) and, currently IDEA under the SWITCH Project have joined efforts in order to find a solution to the complicated situation in the tanneries' community regarding environmental, socioeconomic and legal issues.

A process of analysis and resolution of an environmental conflict started in 2004 and after clearly defining the problem together with the tanning community, Cleaner Production (CP) was chosen and carried out as a technological solution (Sanz, 2007). Cleaner Production (CP), within the context of sustainable water management, is considered an integral preventive strategy to improve the environmental, production, socioeconomic and institutional characteristics of tanneries. This strategy focuses on achieving eco-efficiency of the tanning activities by anticipating, reducing, or preventing their polluting emissions.

Research Goal

The goal of this research was to create an integrated and optimal solution to the environmental and economic problems of the tanneries, one tailored to fit the conditions and the context of the region of Villapinzon and Choconta.

The strategy was focused on water and waste management and performance improvement of the tanneries, and based upon the integration of physical, socioeconomic, productive and institutional components, and on the creation of discussion spaces where all the involved actors can participate.

Research Objective

The research objective is to reduce/eliminate emissions to the environment from the tanning production activities, by implementing improvements in the whole process.

2. Background

2.1. Process technology description in an average Colombian tannery

The first tanning activities in Colombia have been traced back to the 1920's in the Province of Antioquia, and in 1950 in Villapinzon and Choconta in the Province of Cundinamarca. Currently, there are tanneries in Nariño, Quindío, Risaralda, Cundinamarca, Antioquia, Atlántico, Valle del Cauca, Tolima, Bolívar, Santander and Huila. 77% of them are classified as micro enterprises, 19% as small enterprises, 3% as medium size enterprises[2], and 1 % as large industries (CNPML, 2004). Micro-tanneries use very similar production processes and technologies, the main differences are in the chemicals of input, processing time and controls, and resulting quality of the final product.

This study focuses on tanneries in Villapinzon and Choconta. Most of them are located in estates with areas over 4,000 square meters. It was common practice to establish the family living quarters in the same building where the production processes took place. Although some still maintain that arrangement, nowadays it is not a common feature. Many tanners had relocated their factories because they were illegally invading the river's borders with the industrial building.

Most factories contain electrically-driven rotary drums, pools, electric water pumps, compressors and water storage tanks; their number varies according to the production capacity. If the production process includes a painting stage there is a special booth with compressors. The supporting industries have polishers, trimmers and machinery to stretch skins. The main products of the regional tanneries are leather for bags, lining and nappa types used in apparel and shoemaking industries. Some of the production goes to upholstery. Several industries produce raw leather (wet blue), process split leather or offer services such as trimming and cutting. Table 1 shows a summary of the leather production processes with a brief description of its different stages.

Photo 1. Processing zone in a tannery producing less than 500 skins per month (CCB, 2004)

Photo 2. Finishing process in a tannery producing less than 500 skins per month (CCB, 2004)

Table 1 Skin tanning process stages

STAGE	OPERATIONS	DESCRIPTION
Preparation	Preserving Transport Reception Conditioning	Skins come from different zones around the country. They are preserved with common salt. No cold-keeping trucks or cold rooms are used in this handling.
Beamhouse	Soaking Unhairing-Liming	In the soaking operation, skins are rehydrated and swollen, impurities are removed. During Unhairing, dermis is softened and hair is retired. In conventional way of

[2] According to the definitions presented in article 2° of the Law 905 of 2004. Micro enterprises are production units with a maximum of 10 employees, small enterprises have among 11 and 50 employees and medium size enterprises have among 51 and 200 employees.

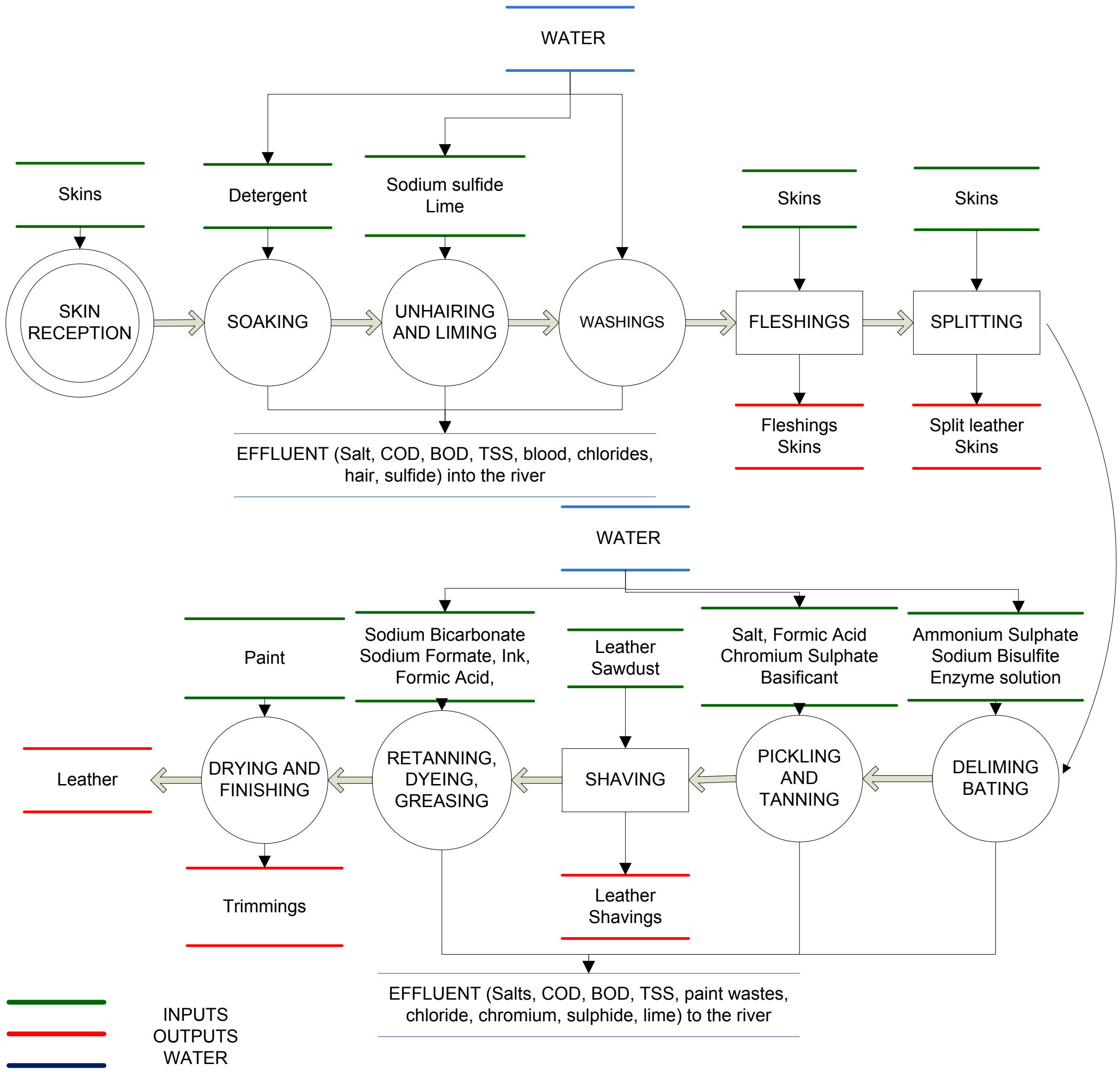
	Fleshing Cutting	processing, hair is destroyed and dissolved into wastewater. In fleshing, inner layer of skin (with most grease contents) is removed and in the last operation, skin is split in order to obtain the grain side, so called "flower", and, as a by-product, split leather, that is trimmed and finished as suede.
Tanning	Deliming Pickling Tanning Shaving	In the tanning stage, chemicals are added to stabilize grain side, and prevent rotting. At first, during deliming, excess lime is removed; swelling decreases and alkalis are removed. Then, in pickling stage, pH is reduced to facilitate tanning and hydrolyze collagen. In tanning operation, chromium salts are added to stabilize proteins. Tanned skin is thinned using a machine which cuts leather fibres off called shaving, for giving an even thickness and uniformity to grain side.
Finishing	Neutralizing Re-tanning Dyeing Greasing Drying Conditioning Stretching Trimming Toggling Pressing Dimensioning	The finishing operations give leather its softness, elasticity, glowing and desired physical and mechanical properties, such as resistance to abrasion, tear and flexion.

Chemicals are dosed according to the estimated weight of skins to be treated. Data on this variable is sometimes given by transportation documents, but normally the tanner does a rough estimate. No exact measurements are made. The amount of skins fed to the drums in one batch depends on the drum size, size and type of raw skin and desired finishing of the product.

2.2. Inputs and Outputs in an average Colombian tannery.

Most of the tanneries have a similar production process. Added chemicals vary according to different suppliers and effluent characteristics depend on the production efficiency. Figure 2 shows a flow diagram of the tanning process, with its inputs and outputs. It was the usual practice in the region that tanneries dumped wastewater with its polluting load directly into the river without any treatment (CCB, 2004). Recently, an Environmental Management Program (EMP) was designed and put into practice, by which it was compulsory for every tannery to build at least a primary treatment system for effluents.

Figure 2 Inputs and outputs of the classical tanning process



2.3. Overview of Best Available Technologies (BAT) in the tanning industry

Table 2 shows the BAT from both national and international sources.

Table 2 Bibliographical review of BAT

PROCESS	TECHNOLOGY	ADVANTAGES	DISADVANTAGES	EQUIPMENT/ MATERIALS	SOURCE
Soaking	Salt recovery	○ A large percentage of salt is recovered ○ Salt in the effluent discharge is reduced Reduction in soaking time	○ Skin can be ripped, depending on drum rotation speed	○ Drum ○ Shaking elements	CPTS Bolivia. 2003, AIICA, CAR/PL 2005
	Batch washing and soaking water reuse	○ Lower water consumption in soaking operation	○ An uncontrolled enzymatic attack may occur, due to water reusing during soaking	○ Drum, water storage tanks	CPTS Bolivia. 2003
	Addition of biodegradable bactericides and surfactants	○ Better moisturizing of skins Reduction of contaminant load in water. ○ Minimization of bacterial attack.	○ Temperature should be maintained below the optimum to prevent the growth of bacteria.	○ Bactericides: dipropylene glycol, (2-thiocyanomethyl) benzothiazol. Surfactants: Sodium lauryl ether sulfate	EPA and CIATEC 2006
Unhairing and Liming	Ecological unhairing Hair immunization	○ Reduction in organic load and suspended solids. ○ Hair can be used in other processes. ○ A high quality hairless skin is obtained.	○ Process should be well monitored, as to prevent lime from penetrating hair root, as difficulties could arise in subsequent hair removal.	○ Drum, filter, reduction and alkalines agents	EPA and CIATEC. 2006, AIICA and CAR/PL. 2005
	Recirculation of unhairing bath water	○ Decrease in pollutant load. ○ Savings in consumption of water and chemical products.	○ Solids should be separated before recirculation. ○ Leather quality could be affected in later stages such as re-tanning and dyeing (stains in the skin).	○ Storage tanks for unhairing washing, equipment and laboratory reagents, drum, pump to pass water to the drum, filter, piping	EPA and CIATEC. 2006, CPTS Bolivia. 2003
	Unhairing by a depilatory paste	○ Hair can be reused in other processes. Reduction in water consumption and sulfide load.	○ Skin quality may be affected by a prolonged contact with the depilatory paste.	○ Machine for applying the paste, drum for rinsing	www.cueronet.com

PROCESS	TECHNOLOGY	ADVANTAGES	DISADVANTAGES	EQUIPMENT/ MATERIALS	SOURCE
	Enzymatic unhairing	○ Decrease in consumption and discharge of sulfide. ○ Reduction in foul odors generation.	○ Enzymes can cause damage to the skin if operation is not well controlled. Water consumption is greater due to additional rinsing.	○ Bacteria cultures. Drum	CPTS. Bolivia. 2003
	Unhairing with sodium acid sulfide and calcium chloride	○ Subsequent pickling and tanning operations are facilitated ○ Handling and disposal of lime mud is avoided ○ Suspended solids and organic load is reduced in the effluent ○ Hair is recovered and reused.	○ pH should be controlled, since a modification of this variable may produce gaseous hydrogen sulfide	○ Drum ○ Storage tanks for the unhairing wash, ○ Filter	CPTS. Bolivia. 2003
	Unhairing by fermentation or staling	○ Hair is recovered and reused.	○ Skin remains attacked by putrefaction and because of this its quality may be affected	○ Drum, humidity and temperature conditions, microorganisms. Filter	www.cueronet.com
Fleshing	Fleshing prior to unhairing	○ Reduction of chemicals in unhairing. ○ Reduction in greases and organic load in the effluent. ○ Wastes may be used as they are not contaminated. ○ Increase of the unhairing efficiency.	○ When skins are too dirty, they may be damaged because of differences in thickness due to the presence of manure.	○ Machine with calibrated blades to avoid a second defleshing	CPTS. Bolivia. 2003 AIICA and CAR/PL 2005
Deliming and purge	Deliming with carbon dioxide	○ Reduction in ammonium salts. ○ Elimination of ammonia odor.	○ Cost may be increased to provide excess CO2 and control the leaks of the drums. In thicker skins, organic additives could be needed to reduce penetration times.	○ High-pressure cylinders and heat exchangers	EPA y CIATEC. 2006, CPTS. Bolivia. 2003
	Deliming with nitrogen-free products	○ Reduction in ammonium salts. ○ Elimination of ammonia odor	○ Not a widely tested alternative.	○ Drum, deliming products	AIICA and CAR/PL 2005
Pickling	Salt-free pickling	○ Reduction in chloride load and sodium ions in	○ The cost of the new inputs are high in Colombian market	○ Drum, Pickling agent tank,	EPA y CIATEC. 2006

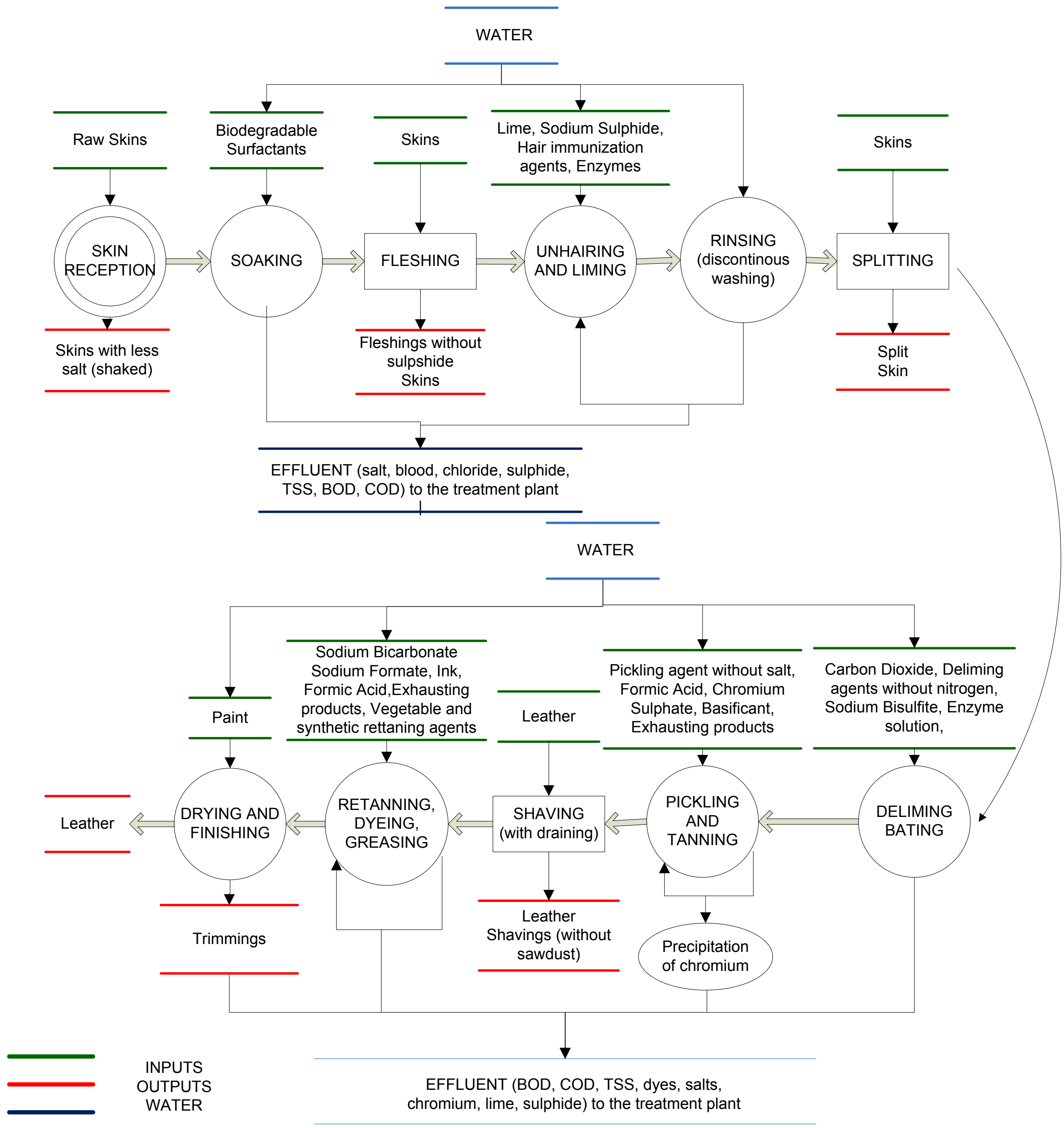
PROCESS	TECHNOLOGY	ADVANTAGES	DISADVANTAGES	EQUIPMENT/ MATERIALS	SOURCE
		the effluent ○ Tanning bath may be reused, since it does not contain neutral salts. ○ New products give easy drainage properties to skin.			
	Recycling and recirculation of the pickling bath	○ Reduction in water, salt and acid consumption	○ Greases and solids have to be filtered before recycling of the bath. Damages can be caused.	○ Drum Storage tanks for recycling baths, filter	EPA and CIATEC. 2006
Tanning	High level of chromium exhaustion	○ Tanning efficiency approximately 95%. ○ Reduction of residual chromium in the effluent. ○ Reduction in the consumption of chromium and water. ○ Not excessive modifications required.	○ Stricter control should be maintained throughout the process. ○ Increasing the temperature may jeopardize quality of final product. ○ Non conventional chemicals can increase costs.	○ Drum, Tanning products, pH measuring equipment, thermometer	UMA, CNPML, Ministerio de Salud y Ambiente, Ministerio de Economía y Producción. Argentina, 2005. EPA and CIATEC. 2006 CPTS. Bolivia, 2003
	Recirculation of chromium baths	○ Reduction of consumption and discharge of chromium. ○ Reduction of salt or other pickling agent discharge. ○ Reduction of water consumption.	○ More variables should be strictly controlled to get a good product. ○ An additional compound may be possibly needed in order to totally settle suspended solids or greases present in the bath	○ Tanks for recycled tanning bath. Laboratory reagents and equipments.	EPA y CIATEC. 2006. CPTS. Bolivia, 2003. CNPML, 2004
	Chromium recovery by precipitation and re-dissolution	○ Reduction of the chromium discharge into the effluent ○ Decrease in chromium consumption. ○ Savings in cost of chemicals. ○ Lower treatment costs	○ Process costs are greatly increased, due to the additional chemical agents. ○ Demands a strict control as it can diminish the quality of the product ○ Operating cycle is likely to increase as settling can be slow	○ Storage tanks for chromium liquor. Tank for flocculation of greases. ○ Pump to send liquor to the tank. ○ Settling tank. Filter press.	UMA, CNPML, Ministerio de Salud y Ambiente, Ministerio de Economía y Producción. Argentina, 2005. EPA y CIATEC 2006.
	Vegetable tanning	○ There are no chromium residues in	○ May increase costs. ○ Product quality may be lower	○ Drum, vegetable extracts, fungicides, acids and storage	Ministerio de Medio Ambiente Spain. October 2003

PROCESS	TECHNOLOGY	ADVANTAGES	DISADVANTAGES	EQUIPMENT/ MATERIALS	SOURCE
		the effluent	as compared to a chromium-based tanning process.	tanks for the previously mentioned products	
	Use of aluminum salts instead of chromium.	○ Colorless, opaque skin smooth to the touch. ○ Aluminum salts combined with chromium salts can produce a chromium high exhaustion.	○ Aluminum salts are not stable alone.	○ Drum, aluminum salts and possible additional reactive agents in order to improve the quality of the tanning	Cueronet, Ministerio de Medio Ambiente Spain. October 2003
	Use of titanium or zirconium instead of chromium	○ Zirconium and titanium salts may come to be less toxic than chromium ones.	○ Control of the process is difficult	○ Drum, Zirconium or titanium salts and additional tanning agents	INTEC CHILE 2000
	Organic Tanning	○ No chromium in the effluent.	○ It is considered a high costs process ○ The presence of free aldehydes and monomer acrylic acids	○ Drum, polymer resin	Ministerio de Medio Ambiente Spain. October 2003
Re-tanning	Use of non-ammonia containing products	○ Reduction in nitrogen and COD load.	○ Controlling the use of neutralizing salts in order to avoid wastage of reactive agents and discharge of salts into the effluent	○ Drum, neutralizing and re-tanning products	CPTS. Bolivia. 2003
Dyeing	Recycling dyeing bath	○ Reduction in the consumption and discharge of dyes. ○ Reduction in water consumption. ○ No special investment in machinery or inputs are required.	○ Strict control variables may increase in order to achieve a good product ○ An additional compound may be needed to settle suspended solids or greases that are in the bath.	○ Storage tanks for dyeing bath; laboratories for the analysis of the baths that are going to be recycled; equipment and laboratory reactive agents.	EPA and CIATEC 2006. CPTS. Bolivia. 2003 CNPML, 2004.

2.4. Inputs and outputs of BAT tannery

Figure 3 shows inputs and outputs in a tanning production process adopting cleaner practices. As compared to Figure 2, the use of different chemicals and a modified order of unit operations can be observed in order to prevent the contamination of the solid waste with chemical substances. Due to an improved efficiency in operations and the adoption of so called "ecological" processes, the polluting load of the effluent will be less than current practice.

Figure 3 Inputs and outputs of a cleaner tanning process



2.5. Conditions and requirements for improving the tanning industries

Implementing a successful environmental/economic improvement program in any existing productive activity depends on the entrepreneur's approach to prevent contamination and on the adequate use of human and environmental resources. For the tanners, this systematic approach particularly implies adapting the resources and capabilities to a changing scenario and to grasp the opportunities derived from the improvement process.

Medium-, small-, and micro-size industrial units face particular challenges in an improvement process due to their limitations in labor, technical and financial resources. Around the world, however, examples of CP implementation in these industries show that challenges must to be seen as opportunities and environmental and productive benefits can ripen (Van Berkel, 1999).

Micro enterprises have some advantages over bigger organizations in ensuring the effectiveness of their environmental management, as their structure is less complex. Communication lines are shorter, employees have multiple functions and top management is readily accessible (ICONTEC, 2004).

Supported on a manual developed as part of the CP program for owners and employees of small and medium enterprises in Australia (Centre of Excellence in Cleaner Production, 2001), the most important stages for CP implementation in a production activity are:

1. Planning and organization (Showing to the enterprises the environmental and economic benefits of CP. Identifying materials, waste, energy and water quantities and cost)
2. Listing of alternatives (Reviewing process, identifying causes of inefficiencies in material, waste, energy and water. Generating and screening CP options)
3. Selection of alternatives (Assessing the feasibility of CP options and preparing the action plan of CP)
4. Implementation and follow-up of selected options (Designing the evaluation plan for CP options)

CP, as an improvement preventive strategy, entails five prevention points (USEPA, 1988; 1992; UNEP, 1994 cited in Van Berkel, 1999).

- Good operational practices
- Chemicals' substitution
- Technological changes
- On-site reusing, recovering and recycling
- Product modifications

In this improvement process, the owner must be ready to establish contacts with environmental authorities, tanneries' associations and organizations, in order to collect available information, exchange experiences and make clear the procedures to be applied.

2.6. Socioeconomical Constraints

2.6.1. Social Constraints

Micro tanneries in Villapinzon and Choconta show a very slow acceptance rate of CP practices. This is mostly due to human factors, to the the fact that most tanners in this region have received technical knowledge from their predecessors, and it's difficult to change their current production practices.

One of the most important constraints of CP implementation is the fact that some years ago, authorities convinced tanners of adopting "end-of-the-pipe" solutions through legal pressure. This contributed to the creation of a collective idea that the only way of running an environmentally acceptable tanning operation was the construction of a primary treatment system[3] in each industry. This approach is endorsed by government policies and regulations.

Another practical constraint arises from the very low educational level of the tanneries' owners and operators, which makes the training process difficult and slow and as a consequence so also the adoption of a different strategy as recommended by environmental authorities for years. Most owners do not know how to treat waste water or how to dispose the waste they generate. They do not identify which of these residues are dangerous or if these can be transformed into a product with added value.

2.6.2. Economic Constraints

Tanners face many economic problems. The most important one is the low rate of use of installed capacity. Other problems are:

- Scarcity of raw hides due to national fluctuations in cattle slaughtering and the role of middle-men.
- The absence of a distribution chain.
- Price fluctuations of leather products on the global market (DNP, 2004).
- High investment costs of new types of chemicals.
- Image problem; their product is seen as poor quality.

Tanneries from this region are not part of a leather production chain. On one hand, skin supply is made through brokers, instead of directly from slaughterhouses. On the other hand, their quality product is low and this excludes them from fair priced national markets, not to speak about international markets.

Even in the face of all the above referred difficulties, the tanning productive process in Choconta and Villapinzon has a remarkable economic importance for the region, as it intensively uses direct and indirect labor and makes use of cattle slaughtering products, which otherwise would be wasted with worst environmental effects.

2.7. Legal Constraints

The main legal constraints in most of tanneries in Villapinzon and Choconta are the tendency to operate informally and the lack of coordination and planning between involved sectors. Most tanneries do not fulfill the requirements for being legally established as companies and are not members of the Bogota Chamber of Commerce (CCB). Minimal requirements for being formally recognized are the adoption of an Environmental Management Plan (EMP), to have a waste dumping permit, the water intake license and the construction of a primary treatment system.

In 1999, CAR started disciplinary proceedings for every tannery in the region, demanding from them the submission and implementation of an Environmental Management Plan (EMP). Many of the plans submitted to CAR were not approved by that same institution, and some were not even reported. During 2005, with the support of the CCB under a conflict resolution scheme, 66 tanneries submitted EMP's to CAR and received technical approval for the very first time in the history of this conflict. Currently, final approval of requirements is pending legal

[3] Primary treatment consists of basic physical-chemical processes to remove the major pollutant in the wastewater, such as COD/BOD, sulfide and chrome (UNEP, 1994)

proceedings due to the lack of approval of the so called Tanneries' Special Plan, a study defining the use of land in the region and not dependant on the tanners.

As the submitted EMPs were put into CARs consideration, a waste dumping and water concession[4] permit was to be applied for with the same environmental authority, which included documentation to support these permits. However in order to grant the permits CAR demanded the preceding commissioning of the treatment facilities that were announced in the EPM's. In the end, and as a fruit of the lobbying efforts by ACURTIR (Villapinzon and Choconta tanner's Association), CAR accepted to lift the ban on those tanneries that formally promised not to discharge chromium or sulfides into the river, as an interim measure, awaiting a full EMP implementation.

Finally, an important constraint to be taken into account is that the environmental regulations do not stimulate the prevention of contamination. Therefore, the measurements adopted and recommended by environmental authorities favor end-of-the-pipe solution alternatives. Moreover, the control and follow up to any improvement are deficient. Some illegal tanneries are dumping effluents contaminated into the river and they are not controlled, but the enterprises that are committed with improving their performance are strictly controlled.

3. Methodology

In order to reach the research objective implementing improvements in the whole process of the tanning industry, a methodology designed by IDEA technical team was adopted. The scheme to apply in the improvement process is composed by a group of feasible technologies according to the regional situation and a pilot group of tanneries committed with their improvement. The technologies were selected based on the overview of BAT for tanneries shown in Table 2. The pilot group was selected over data obtained from the files of legal actions of CAR in 2007, regarding the type and number of tanneries.

Subsequently, the expected benefits of the CP implementation process were evaluated through an identification of impacts applying a methodology of environmental impact assessment (Conesa, 2003). This implementation process includes the selected technologies and other type of actions that are not part of the productive process.

Finally, the strategy to follow up the implementation in the pilot group of tanneries is presented, including the sampling procedure of waste water that was designed according the development of the tanning process.

3.1 Selection of BAT

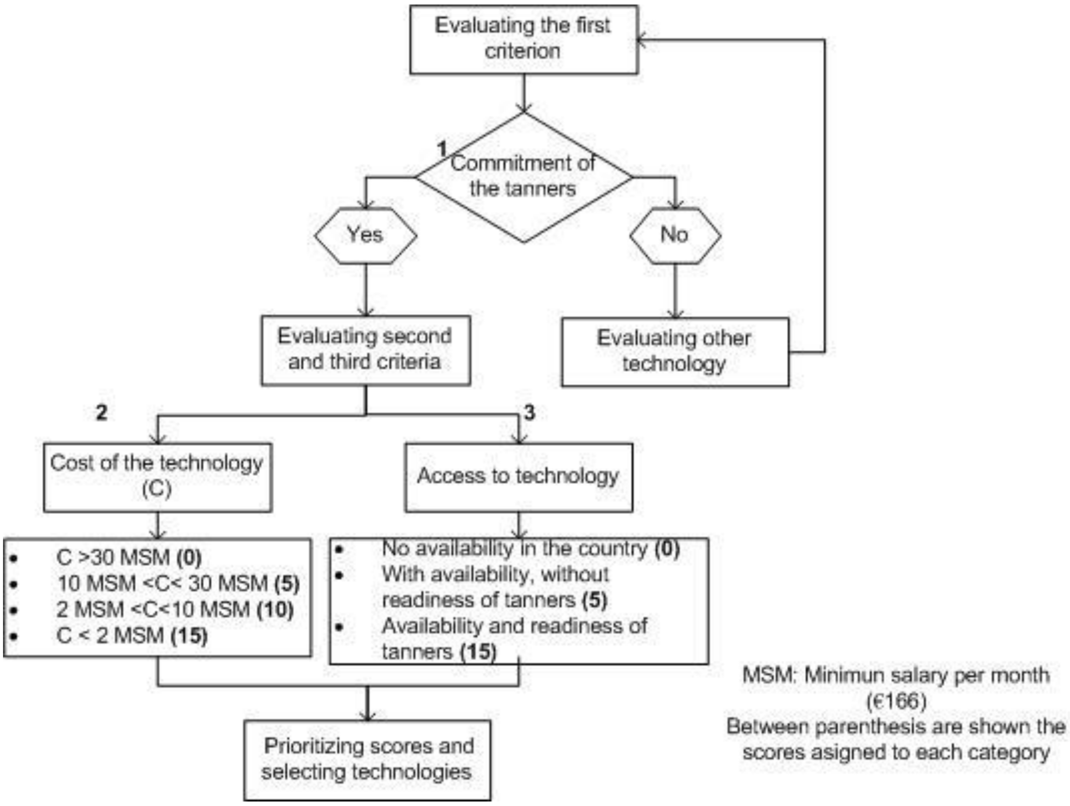
In order to select the more feasible technologies, economic, social, technical and technological matters were taken into account. Three criteria were included for evaluation and different scores were given for each one. Prioritization was the result of adding up the scores derived from the application of the criteria. Selected technologies were those obtaining the highest scores.

Figure 4 shows the selection criteria used in prioritizing the alternatives. The first criterion is the commitment of tanners to implement the technology. If the response is negative, this

[4] A water concession is a license granted by environmental authorities for the optimal use and exploitation of the water resource taking into account the technical conditions of its availability, supply and purpose of the resource. According to Decreto 1541 de 1978.

technology is ruled out. The second criterion is the cost of the alternative, given as a rank of the minimum salary per month in Colombia in 2007 according to the order in council 4580 de 2006 (C$ 433.700 equivalent to € 166[5]). The third criterion is the access to the technology, where its availability and the owner's readiness for implementation are evaluated.

Figure 4 Process of technologies selection



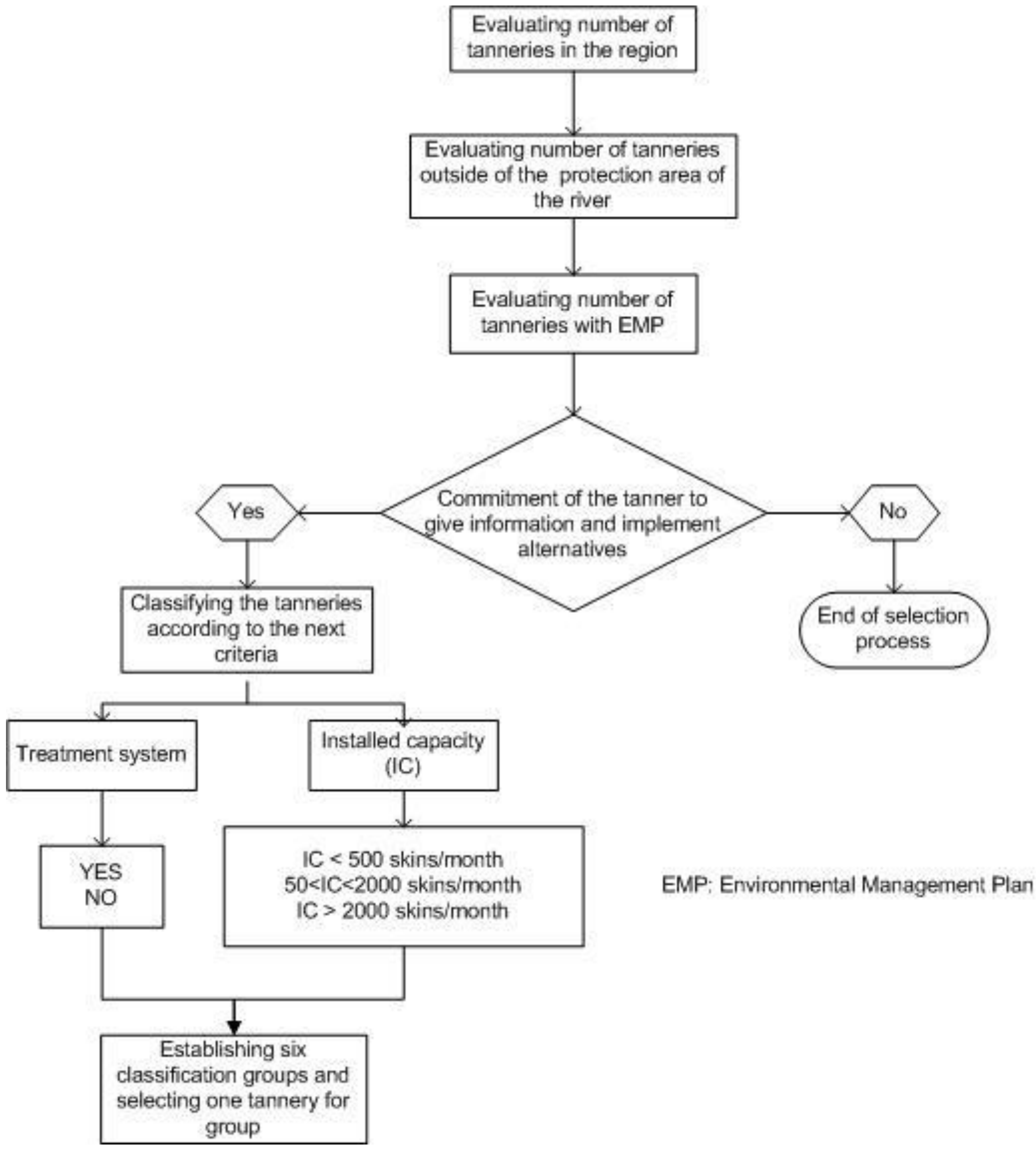
3.2. Selection of tanneries

For the selection of the tanneries where the field test will be executed, initially a census of existing tanneries was made in the Villapinzon area. The selection criteria included the establishment of the industries outside of the flooding risk area, the production capacity and the tannery's affiliation with the tanner association, ACURTIR.

In order to obtain a cross sectional sample, the tanneries were classified according to production capacity and the existence of a water treatment. Six groups were established, based upon the combination of these two criteria (Figure 5).

[5] Exchange rate 2614.5 pesos for 1 euro. Revista Portafolio, 25 de junio de 2007

Figure 5 Process of tanneries selection



3.3. Evaluation of the expected benefits of the CP implementation process

The CP implementation process includes the technologies selected below and other groups of actions that potentially impact different factors in tanneries. These other groups are related with social, economical and institutional matters.

In order to identify and analyze the expected environmental benefits of all actions, their current impacts were established regarding ecological, sociocultural, legal, economical and institutional components. After that, a prospective scenario was constructed, in which impacts were estimated with and without CP implementation in the tanneries.

As a tool for assessing environmental impact, a qualitative methodology was adopted (Conesa, 2003). This methodology allows the identification the groups of actions projected in the implementation process that can generate impacts.

The identification and prioritizing of sociocultural, economical, institutional and environmental management factors were supported by the work of an expert panel. The experts helped identifying, classifying, evaluating and weighting each factor (Delphi method) (Conesa, 2003). Qualitative valuation was achieved by means of an informatics application (Visual Basic 5.0) and taking into account eleven attributes of each evaluated impact. After this work was concluded, an accurate estimation of benefits to be obtained from CP alternatives implementation was available.

3.4. Follow up to the CP implementation

The follow up to CP implementation in each tannery was designed taking into account the five points of action mentioned in Table 3. For monitoring each general technique of the point weekly checks were made in the industries using a check list. At first, there was a check on current practices of industrial safety, equipment and its maintenance records, raw materials inventory and control instruments. Through training sessions addressed to owners and operators, an improvement in these subjects will be promoted and followed up. Finally, there will be checks on the improvements of process technologies and management of by-products and waste.

For technologies selected, the experimental test was carried out within a productive process in one tannery and wastewater was sampled at the end of each operation to share with conventional technology. Table 3 describes the quality parameters to be measured.

Table 3 Parameters to be measured in each operation of the production process

PARAMETER	Soaking	Unhairing	Deliming	Pickling and tanning	Retanning	Dyeing and fatting	Treatment system
BOD	X						X
COD	X	X	X	X	X	X	X
TSS	X	X	X	X	X	X	X
Cl -	X	X		X			X
Fat and Oil		X		X		X	X
Lime	X	X					
Kjelldahl Nitrogen (TKN)			X				
Sulfide		X	X				X
Conductivity, pH, temperatura			X				
Hexavalent Chromium				X	X		X
Trivalent Chromium				X	X		X
4 heavy metals according to the dyes used.						X	X

The general procedure employed in sampling the wastewater in the Villapinzon's tanneries is composed by seven steps, as follows:

1. Evaluating water flow into the drum
2. Carrying out operation according to the recipe (Register data)
3. Water discharge
4. Measuring water discharge
5. Measuring *in situ* variables (pH, temperature, conductivity, density) (Register data)
6. Fill water into a bottle

7. Transport the samples to the laboratory

The monitoring program, the indicators used to share classical and cleaner processes and the frequency of measurements will be explained in detail in document D4.2.4, on development of the conceptual design of the environmental monitoring program for tanneries.

4. Results

4.1. Description of selected tanneries for field testing of improvement options

Table 4 shows a general description of selected tanneries highlighting the company size, main products, headcount and installed capacity (IC). Not a single tannery operates on a continuous cycle and all are classified as micro companies according to the number of employees.

Table 4 General description of tanneries

Tannery	Total Area (m^2)	Built Area (m^2)	Main products	Employees*	Installed capacity (IC) (skins/month)	Production per month (% of IC)
Villasol	6811	88	Liner, gamuza, blue leather	2 O and 2 PT	500	60
Rosendo Castiblanco	1500	500	Tula and liner	5 O and 2 PT	500	60
Alaska	2500	500	Tula, nappa, blue leather	2 O and 4 PT	1000	70
La pradera	6878	400	Tula, nappa, blue leather	2 O and 2 PT	3000	17
Montecarlo	3600	2000	Tula, fine leather work	7 O and 4 PT	3000	67
Curtinorte	2050	500	Tula, fine leather work	2 O and 4 PT	3000	67

*O: Owners PT: Part time employees

4.2. Description of improved process

Improved operations are described in Table 5, in terms of input chemicals change, recipe modifications and control of process and product.

Table 5 Description of improved tanning process

STAGE	OPERATIONS	DESCRIPTION
Preparation	Preserving Transport Reception Conditioning	Using cold-keeping trucks or cold rooms. Having dedicated places for the storage of skins. Using fresh skins or shaking off the salt to reduce chlorides load. Monitoring the pH, bath density and temperature. It is assured that chemicals uniformly penetrate skins and an open fiber, soft and resistant structure is obtained and the quality increase.
Beamhouse	Soaking Unhairing-Liming Fleshing Cutting	Adding biodegradable surfactants to remove the dirt from the skin. To monitor pH and bath density. To verify correct hydration to the touch. Carrying out fleshing after soaking. Before unhairing to add lime for the hair immunization and to avoid its destruction. To add inputs, then discharging and filtering water. Splitting skins to obtain grain side and split leather as by-product, used in other productive processes. Monitoring the pH, bath density and temperature.
Tanning	Deliming Pickling Tanning	In deliming, using deliming agents different to the conventional ones (e.g. carbon dioxide and free nitrogen products). Carrying out pickling reducing conventional quantity of salt and using

	Shaving	other pickling agents different to salt. In tanning, to add exhausting products improve efficiency (85%) reducing waste chromium. Shaving tanned leather to level thickness. To monitor pH and bath density. Monitoring the pH, bath density and temperature.
Finishing	Neutralizing Re-tanning Dyeing Greasing Drying Conditioning Stretching Trimming Toggling Pressing Dimensioning	Using retanning agents must free nitrogen. Adding exhausting agents in dyeing to reduce dyes in effluent and improving efficiency of the operation. To put in practice the equipment maintenance due to in the last operations, big quantities of energy are consumed. Monitoring the pH, bath density and temperature.

4.3. Selected technologies of process per tannery

Owners selected the CP technologies to implement based on their experience, their investment capability and economic resources and the ease of application. Table 6 shows which tannery selected what technology.

Table 6 Technologies of process per tannery

TECHNOLOGY	TANNERY					
	ROSENDO CASTIBLANCO	CURTINORTE	ALASKA	MONTECARLO	VILLASOL	LA PRADERA
Good operating practices	●	●	●	●	●	●
Manual salt recovery	●	●	●	●	●	●
Batch washing	●	●	●	●	●	●
Adding biodegradables bactericides and surfactants	●	●	●	●	●	●
Ecologic Unhairing with hair Immunization	●	●	●	●	●	●
Unhairing bath recycling		●	●			●
Defleshing prior to Unhairing		●		●		●
Deliming using carbon dioxide		●				
Deliming with nitrogen free products				●		
Recovering deliming purges			●			●
Pickling without salt					●	
High chromium exhaustion	●	●	●	●	●	●
Recycling chromium baths	●					
Chromium recovery	●					
Dyeing bath recycling			●			

4.4. Assessment of pollution reduction per improvement alternative

Table 7 presents information about the pollution level reduction as given by references for each technology selected in the industry.

Table 7 Pollution reduction per technology

PROCESS	TECHNOLOGY	PARAMETERS TO BE REDUCED	REDUCTION	SOURCE
Soaking	**Manual salt recovery**	Chlorides in wastewater	Chlorides: 8 - 10%	Ludvik, 2000 Aloy *et al.* 2000
	Batch washing	Water consumption and waste volume.	60% of water	EPA, CIATEC A.C. 2006
	Addition of biodegradable surfactants	COD, Volume of soak water discharged	COD: 90 - 95 %; discharged water 20 - 25 %	AIICA. 2006
Unhairing and liming	**Ecological unhairing with hair immunization**	BOD, COD, TSS, Sulfides	30 - 50 % in COD and BOD in the effluent	Aloy *et al.* 2000 INTEC CHILE, 2000 European Commission, 2001
			50 % in the amount of sulfide in the effluent	
			50% of suspended solids in the effluent.	
			50 – 70% in TKN	
			20% in wastewater	
	Unhairing bath recycling	COD, total Nitrogen kjeldahl, sulfides total solids, water.	30 to 40% COD in wastewater	European Commission, 2001 Aloy *et al,* 2000
			15 to 40% total nitrogen in wastewater	
			Up to 40% of sulfide	
			Up to 50% of lime	
			50 % SST in the effluent	
			70% water discharge.	
Fleshing	**Fleshing prior to unhairing**	Consumption of chemical products, water, COD and BOD	10 -20% in chemical consumption (reduction in waste water)	European Comission, 2001
Deliming	**Deliming with nitrogen-free products**	Lowering deliming time, and reducing ammonia nitrogen in the effluent	About 95 % in the amount of ammonium nitrogen in the effluent	Ludvik, 2000
	Deliming with carbon dioxide	Nitrogen, total Nitrogen kjeldahl in the effluent	60% to 65% in ammonium nitrogen	European Commission, 2001.
			30 % to 40% in chemicals consumption	
			20 to 30 % discharges of total Nitrogen kjeldahl	

Pickling	**Pickling without salt**	Chlorides, dissolved salts and conductivity in wastewater	80% of salt content, chlorides. 20 to 25 % of either formic or sulphuric acid	Aloy *et al,* 2000
Tanning	**Recycling chromium baths**	Total chromium in the effluent, residual tanning water volume discharged	20% of chromium used 90% water discharged as the whole lot is recycled 40 – 60% chromium in the effluent	Aloy *et al,* 2000 EPA, CIATEC A.C. 2006 European Commission, 2001.
	Chromium recovery	Total chromium in the effluent, chromium consumption in the following process of tanning	90% of chromium 30% of total chromium salt consumption	European Commission, 2001.
	Chromium exhaustion	Chromium in wastewater	32,7 % Chromium consumption 50 – 80% chromium in wastewater	INTEC CHILE, 2000
Dyeing	**Reutilization of dyeing baths**	Reducing amount of discharged water and concentration of highly toxic dyes in the effluent.	About 90% of dyes pollution, and it avoids water discharging.	EPA, CIATEC A.C. 2006

4.5. Mass Balance Description

4.5.1. Average mass balance in a conventional process

For each unit operation in the tanneries, inputs were measured (raw material, process water, chemicals and others), as well as outputs (intermediate or final product, by-products, solid and liquid waste and losses). Losses normally correspond to spills or leakage due to equipment malfunctioning, measurement uncertainties or inadequate handling of raw materials, chemicals.

Most tanneries don't have a water meter. Some tanners have faced difficulties in the water meters installed due to the bad maintenance of the entry lines. Estimates on water use are made by several measurements of the filling time of a known volume container.

Table 8 shows the mass balance of the selected tanneries established with data gathered in 2004 and 2005, by the Project of EMP led by CCB. Current data was collected from the tannery owners, according to the recipe employed in each. Values shown are averages and standard deviations for the six companies and expressed per unit of weight of finished product. The water quantities are expressed per 10^3 kg/kg of finished product.

Table 8 Mass Balances in a conventional tannery production process

Input (*/kg finished product)	AVERAGE	STANDARD DEVIATION	OPERATION	Output (*/kg finished product)	AVERAGE	STANDARD DEVIATION
Water[a] (m^3)	10,94	2,17	SKIN RECEPTION AND SOAKING	Water (m^3)	9,67	2,66
Skins (Kg)	4,23	1,88		Salt (Kg)	0,07	0,04
Detergent (Kg)	0,003	0,002		Skins (Kg)	4,73	2,35
Skins (Kg)	4,73	2,35	UNHAIRING AND LIMING	Water (m^3)	6,98	3,97
Water (m^3)	7,84	3,72		Skins (Kg)	5,52	2,45
Sodium Sulfide (Kg)	0,07	0,03		Hair (Kg)	0,07	0,06
Lime (Kg)	0,18	0,09		Lime (Kg)	0,06	0,10
				Sodium Sulfide(Kg)	0,019	0,017
Water (m^3)	9,28	6,95	RINSING	Water (m^3)	9,07	6,53
Skins (Kg)	5,18	2,12		Skins (Kg)	5,65	2,21
Skins (Kg)	5,65	2,21	FLESHING	Fleshings (Kg)	1,06	0,32
				Skins (Kg)	4,42	1,97
Skins (Kg)	4,69	2,43	SPLITTING	Grain side leather (Kg)	2,14	0,82
				Split leather (Kg)	2,15	1,03
Leather (Kg)	2,18	0,97	DELIMING	Water (m^3)	4,96	2,04
Water (m^3)	4,67	2,04		Leather (Kg)	1,78	0,83
Ammonium sulphate(Kg)	0,031	0,017		Ammonium sulphate (Kg)	0,006	0,012
Sodium bisulfide (Kg)	0,014	0,018		Sodium bilsulfide (Kg)	0,004	0,006
Other inputs (Kg)	0,018	0,016		Other inputs (Kg)	0,010	0,005
Leather (Kg)	1,90	0,91	RINSING	Water(m^3)	21,08	18,03
Water (m^3)	21,05	17,98		Leather (Kg)	1,78	0,83
Leather (Kg)	1,90	0,91	PICKLING AND TANNING	Water (L)	4,03	2,76
Water (m^3)	4,20	2,66		Leather (Kg)	1,78	0,69
Salt (Kg)	0,1182	0,0585				
Formic acid (Kg)	0,0231	0,0212				
Chromium sulphate(Kg)	0,1147	0,0604				
Basificant (Kg)	0,0097	0,0045				
Leather (Kg)	1,78	0,69	SHAVING	Shavings (Kg)	0,56	0,72
				Leather (Kg)	1,35	0,39
Water (m^3)	5,55	4,83	RETANNING, DYEING, FATTING, DRYING AND FINISHING	Water (m3)	4,57	2,82
Leather (Kg)	1,15	0,17		Leather (Kg)	1,23	0,20
Ink (kg)	0,010	0,003		Evaporated water(m3)	0,41	0,39
Fat (Kg)	0,092	0,042		Trimmings (Kg)	0,08	0,07
Formic acid (Kg)	0,005	0,001		Leather (Kg)	1,00	
Leather (Kg)	1,00					

*It corresponds to each unit shown for input

[a] Water quantities are shown per 10^3 kg/kg of finished product

4.5.2 Average mass balance in a cleaner process

Table 9 is the result of a cleaner process recommended by a chemicals supplying company, and it is mainly characterized by unhairing with hair immunization and tanning with high chromium exhaustion. The relation of input skin per finished product applied was the same used in the previous balance (Table 9). The changes were made on the resultant balance according to the effluent reductions by avoiding water discharge (e.g. recycling water in baths of unhairing, dyeing and tanning), to the order of the process operations (e.g. fleshing before soaking), to the new chemicals used (e.g. addition of biodegradable surfactants, unhairing with hair immunization, chromium exhaustion, deliming with free nitrogen agents) and to the reduction in chemical consumption (e.g. pickling with less salt).
In accordance with these modifications and comparing those two balances, reductions of water (70 – 75%), sulfide (40 – 50%), chromium (40 – 50%) and lime (30 – 40%) consumptions are expected.

Table 9 Mass Balance in a cleaner production process

INPUTS	* / KG FINISHED PRODUCT	OPERATION	OUTPUTS	* / KG FINISHED PRODUCT
Skin (kg)	4,11	SKIN RECEPTION WASHING	Skins (Kg)	4,20
Water[a] (m3)	3,51		Salt (Kg)	0,11
Biodegradable surfactants (Kg)	0,004		Water (m3)	3,41
			Biodegradable surfactants (Kg)	0,002
Skins (Kg)	4,20	FLESHING	Skins (Kg)	3,15
			Fleshings (Kg)	1,05
Skins (Kg)	3,15	SOAKING	Skins (Kg)	3,47
Water (m3)	0,70		Water (m3)	0,39
Biodegradable surfactants (Kg)	0,027		Biodegradable surfactants (Kg)	0,027
Sodium hidroxide (Kg)	0,003		Sodium hidroxide (Kg)	0,003
Skins (Kg)	3,47	HAIR IMMUNIZATION	Skins (Kg)	3,47
Water (m3)	2,05		Water (m3)	2,06
Lime (Kg)	0,028		Lime (Kg)	0,025
Immunization agent (Kg)	0,028		Immunization agent (Kg)	0,025
Skins (Kg)	3,47	UNHAIRING AND LIMING	Skins (Kg)	3,17
Sodium sulfide (Kg)	0,04		Sodium sulfide (Kg)	0,002
Lime (Kg)	0,094		Lime (Kg)	0,006
Water (m3)	3,28		Water (m3)	0,98
			Hair	0,14
Skins (Kg)	3,17	SPLITTING	Grain side leather (Kg)	1,49
			Split leather (Kg)	1,68
Leather (Kg)	1,49	DELIMING AND PURGE	Leather (Kg)	1,28
Water (m3)	2,23		Water (m3)	2,04
Ammonium sulphate (Kg)	0,012		Ammonium sulfide (Kg)	0,006
Carbon dioxide (Kg)	0,012		Carbon dioxide (Kg)	0,001
Enzyme for purge	0,003		Enzyme for purge	0,000

(Kg)			(Kg)	
Leather (Kg)	1,29	RINSING	Leather (Kg)	1,29
Water (m3)	1,09		Water (m3)	1,09
Leather (Kg)	1,29	PICKLING AND TANNING	Leather (Kg)	1,79
Water (m3)	0,39		Water (m3)	0,00
Salt (Kg)	0,05		Salt (Kg)	0,00
Formic acid (Kg)	0,013		Formic acid (Kg)	0,012
Chromium sulphate (Kg)	0,067		Chromium sulphate (Kg)	0,00
Exhausting product (Kg)	0,002		Exhausting product (Kg)	0,001
Other inputs (Kg)	0,021		Other inputs (Kg)	0,021
Leather (Kg)	1,79	DRAINING	Leather (Kg)	1,61
			Water (m3)	0,18
Leather (Kg)	1,61	SHAVING	Leather (Kg)	1,36
			Shavings (Kg)	0,25
Leather (Kg)	1,36	WASHING	Leather (Kg)	1,41
Water (m3)	2,04		Water (m3)	2,00
Leather (Kg)	1,41	RETANNING	Leather (Kg)	1,41
Water (m3)	1,36		Water (m3)	1,36
Sodium formate (Kg)	0,005		Sodium formate (Kg)	0,005
Other inputs (Kg)	0,010		Other inputs (Kg)	0,00
Leather (Kg)	1,41	DYEING AND FATTING	Leather (Kg)	1,46
Water (m3)	1,64		Water (m3)	1,64
Inks (Kg)	0,010		Inks (Kg)	0,00
Formic acid (Kg)	0,004		Formic acid (Kg)	0,004
Fat (Kg)	0,039		Fat (Kg)	0,004
Leather (Kg)	1,46	DRYING AND FINISHING	Leather (Kg)	1,02
			Water evaporated (m3)	0,44
			Trimmings	0,02

[*] It corresponds to each unit shown for input
[a] Water quantities are shown per 1000 kg of finished product

4.6. Energy balance description

The tanning process requires electrical, thermal and human energy. Electrical energy is mainly used to drive motors, while thermal is mostly used for steam generation and human energy is measured in terms of time devoted to a particular action by one or more operators.

Micro tanneries in the study region do not use boilers for steam production or heating water. Process water is used at room temperature.

The energy balance, therefore, was calculated, as for electrical energy, taking into account power consumption of the motors driving the drums and of the pumps used for supplying or recirculating water times their respective operational times. As for human energy, equivalence is used between power and work developed by a person (0.25 HP/man)[6] (ESP & UNAL, 1998).

[6] Horse Power: English system power unit.

In order to obtain the energy consumption in each operation, the nominal power of motor, and the time of rotation of the drum must be known, and following equations must be applied (Van Wylen & Sonntag, 1973).

$$P_{(KW)} = 0.7457 * P_{(HP)} \quad (1)$$
$$E_{(KWh)} = P_{(KW)} * t_{(h)}$$

Where: P = motor nominal power (kW or hp)
E= energy consumption (kWh)
t = motor working time (h)
1 hp = 0.7457 kW

Following is an example of energy consumption calculation for a drum having a 9 HP motor and running continuously for 196 minutes.

$$P_{(KW)} = 0.7457 * P_{(HP)}$$
$$E_{(KWh)} = P_{(KW)} * t_{(h)}$$

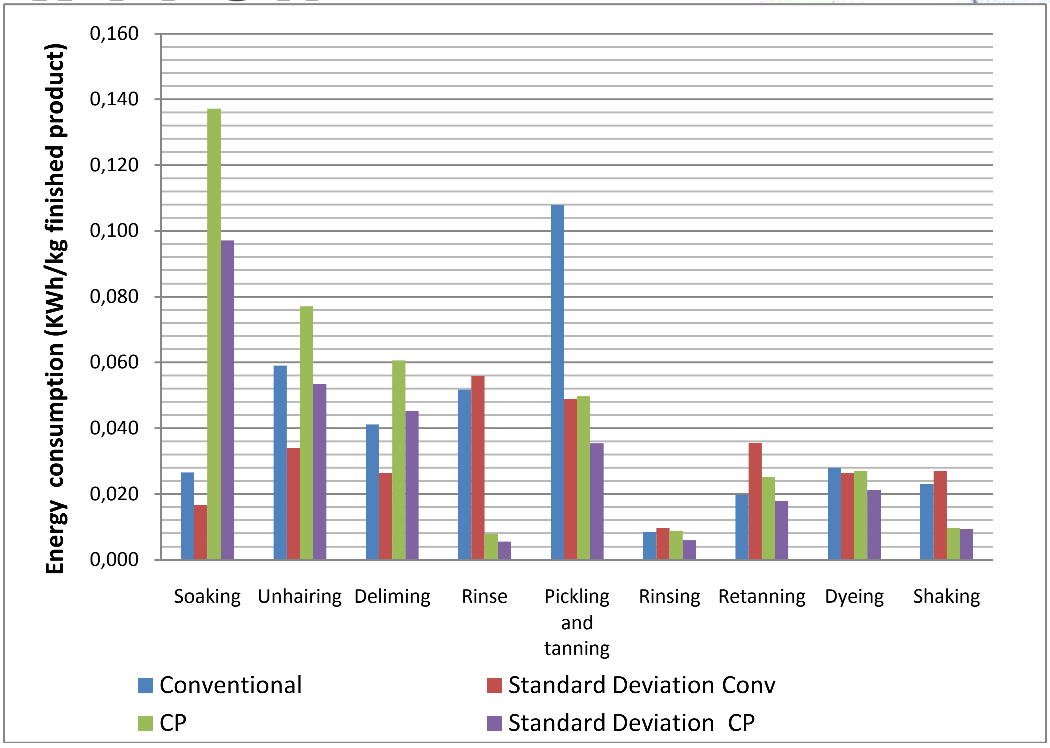
$$P = 0{,}7457 * 9.0 = 6{,}7\ KW$$

$$E = 6{,}7 * \frac{196\,\text{min}}{60\,\text{min}} = 21{,}9\ KWh$$

On the other hand, for estimating human energy consumption, an average power developed by one person was taken into account as well as the time spent in the operation. Applicable equations are the same as above, but power input is always taken as 0.25 HP (ESP & UNAL, 1998). This figure has been developed through previous studies and represents all different factors involved in human physical work.

Graph 1 shows a comparison between the energy consumption of conventional process and modifications according to the selected technologies per unit of weight of finished product. Values shown are the average of the energy balances in the selected tanneries (CCB, 2005), and for CP alternatives, with the operation time found in the bibliography for each of them. Standard deviation of the data is also calculated and presented in the graph.

Graph 1 Comparison of Energy consumption per finished product



4.7. Summary of overall system improvements

4.7.1 Water quality and quantity

Water quality

Table 10 reviews the parameter affected for each technology and the expected reductions for each quality parameter according to the contaminant reduction study in each selected technology.

Table 10 Expected reduction of parameters per process technology selected

AFFECTED PARAMETERS	EXPECTED REDUCTION
COD / BOD	Using biodegradable surfactants (90-94%), Ecologic Unhairing (40-50%), Unhairing bath recycling (15-40%) Defleshing prior to Unhairing
TSS	Ecological Unhairing implementation (50%) Recycling Unhairing baths (50%)
Sulfides	Ecological Unhairing (40 - 50%) Recycling Unhairing baths (50-70%)
Chromium	Reducing its concentration in effluent by high chromium depletion (40% - 50%) Recycling chromium baths (90%) Chromium recovery (90%)
Ammonia Nitrogen	Deliming with nitrogen-free compounds (90%) Deliming with CO_2 (60% - 70%)

Chlorides	Salt recovery by shaking skins (10%) and by SALT-free pickling (90%)
Water consumption	By BOP implementation and water recycling or reuse approximately 60% - 70% reduction.
Waste water	By BOP implementation and water recycling or reuse approximately 70% - 80% reduction.

Table 11 shows the overall reduction expected in each parameter, given an ideal scenario in which every CP alternative was implemented. It was calculated from reductions given in Table 12 and available information about average characteristics measured in 2004 (CCB, 2004). The total reduction percentage per parameter is given by the impact of each operation in which technology is applied. This impact according to the quantity of water consumed and discharged and the contamination load contributed by the operation.

Table 11 Overall reduction expected in water quality discharged with CP implementation

Parameter	Value (Kg/skin)		% Reduction estimated
	Conventional	CP	
Chloride	1,585	0,231	80% - 90%
Total Chromium	0,019	0,003	80% - 90%
BOD	1,045	0,657	30% - 40%
COD	1,783	0,586	60% - 70%
Total Nitrogen	0,136	0,029	70% - 80%
Total Suspended Solides	1,618	0,568	60% - 70%
Sulfide	0,196	0,070	60% - 70%

Water quantity

According to available information on mass balances calculated in 2004 (CCB, 2004) and estimated savings in water in each technology selected (Table 8) the percentages of reduction in quantity of water consumed and discharged are presented in Table 13.

Table 12 Percentages of reduction expected for process technologies

	% Reduction Average	SD
Water consumption	69%	17%
Wastewater	75%	18%

4.7.2 Energy

According to available energy balances made by CCB (CCB, 2004) and new recommended recipes (rotation time modification), reduction in electric energy consumption was estimated for each tannery, according to the production capacity levels (see Table 4). Improvement in energy only can be seen in four operations of the process (Graph 1). Reduction percentages (average and standard deviation) shown in Table 13 are related only with the improved operations.

Table 13 Energy consumption reduction expected for CP alternatives

Energy consumption reduction (Kwh/kg finished product)	Conventional	CP
Average (six tanneries)	0,053	0,024
Standard Deviation	0,039	0,019
Reduction (%)	50%	34%

4.8 Assessment of CP Environmental Impacts

In this section, a review is made of results of the qualitative evaluation made through an environmental impacts matrix, once CP is implemented in each tannery. This evaluation allows identification of the impacts generated by three groups of actions projected in the CP implementation process over the environmental factors identified by an expert panel.

Three types of action were identified for this analysis:

1. General: These are changes that can be adopted throughout the tanning process, for example good operation practices, management and discharge of residues and actions such as inter-institutional management and association capability.
2. Beamhouse: CP strategies to be implemented in the soaking, unhairing and liming operations.
3. Tanning: Modifying the final stage of the process, which is deliming, pickling, tanning and dyeing.

After the qualitative assessment, results show that the general actions of the first group cause the highest impact in the qualitative evaluation over technical actions. This impact is due to the association capability which in turn improves the tanners' economic situation and their sociocultural, legal and commercial status. Any effort in these actions would bring more significant results than the technology change. It must keep during the change process.

5. Discussion

5.1. Environmental consequences of performance improvements (including extrapolation of effects)

Expected environmental benefits of implementing CP in regional tanneries at Villapinzon and Choconta can be measured in terms of the reduction in fresh water consumption and in waste water discharge and a decrease in energy consumption.

Data from CAR in 2007 was used to estimate the type and number of tanneries. Volumes of freshwater not to be used and of wastewater not to be discharged were estimated based on the monthly production capacity and reduction percentages calculated for CP implementation. It is shown in the Table 14.

Table 14 Monthly volumes of not used freshwater and of not generated wastewater if CP were to be fully implemented in the region

TANNERY SIZE	Number	# skins /month	m3 not generated waste water/month	m3 not consumed water / mo.
Micro tannery	28	500	2962	2995
Small tannery	50	2000	21158	21390
Medium size tannery	24	5000	25390	25668
Large tannery	3	7000	4443	4492
TOTAL	**105**		**53953**	54545

Using similar data and reduction percentages, the potential reduction in contaminant load was estimated for each of the water quality parameters of interest and is presented in Table 15:

Table 15 Contaminant load that would be avoided if tanneries of the region will implement CP

PARAMETER	Kg/ skin	Kg contaminant to be avoided / month				
		Micro tannery (28)*	**Small tannery (50)**	**Medium tannery (24)**	**Large tannery (3)**	**TOTAL (kg/month)**
Chlorides	0,231	3228,76	23062,57	27675,08	4843,14	**58810**
Total Chromium	0,003	39,09	279,22	335,07	58,64	**712**
BOD	0,657	9191,56	65654,01	78784,81	13787,34	**167420**
COD	0,586	8199,50	58567,83	70281,40	12299,24	**149350**
Total nitrogen	0,029	410,25	2930,35	3516,42	615,37	**7470**
TSS	0,568	7947,09	56764,94	68117,93	11920,64	**144750**
Sulfides	0,070	980,48	7003,43	8404,12	1470,72	**17860**

*Numbers in parenthesis are the total of tanneries in each size

Table 16 shows an estimation of the reduction of energy consumption, it was made using the same method as in the two preceding tables:

Table 16 Energy not consumed if CP were to be fully implemented

TANNERY SIZE	Number	# skins /month	Not consumed energy (KWh/month)
Micro tannery	28	500	645
Small tannery	50	2000	4605
Medium tannery	24	5000	5526
Large tannery	3	7000	967
TOTAL	105		11744

These quantities of water consumed, discharged and energy consumed would be reached if the tanneries of the region and the authorities comprehend the importance of CP as a strategy that is aiming to achieve environmental and economic benefits. Tanners in region see CP as an expense, not as an investment for improving their industries. Authorities neither understand why end of pipe alternatives are not sustainable for an industrial sector and an integral strategy has to be promoted.

5.2. Social consequences of performance improvements

The environmental impact study identified three socio-cultural variables that would be affected in a positive way by the implementation of CP. First of all, education will ensure that operators and owners in tanneries better grasp relevant information to produce fine quality leather, applying good operational practices and sound environmental procedures. As a result, competitive quality leathers will be produced, and these will be accepted in environmentally conscious markets.

The second variable impacted is the social perception, expressed as the overcoming of mental barriers, changing traditional uses, and establishing public opinion and group (community and institutions) relationships. By implementing CP and thus improving their environmental performance, the public opinion of tanneries will improve and regulatory bodies will be more

willing to hear their voice. The process of implementing CP is made easier by strengthening collaboration and ties with institutions and authorities.
Finally, there will be an improvement in the quality of life for the tanners. By improving their products, processes and environment, they will have better business opportunities, job security and living standard.

5.3. Economic consequences of performance improvements

In order to analyze economic results of implementing CP, the cost of producing one kg of finished product was calculated for two scenarios. The first scenario is based upon data collected in 2007, and includes only direct costs: raw materials, chemicals, labor and energy. The second scenario, named prospective, besides direct costs also includes costs for the payment of public utilities such as: water supply, waste treatment (primary and secondary), dangerous waste disposal, legal counseling and fines.

Costs were estimated for the traditional process and for the improved CP process in both scenarios. The analysis was made using the mass balance from Table 8 for the traditional process and Table 9 for the CP process. It can be observed that in the first scenario (i.e., not including all costs), costs of CP implementation are higher. In the prospective scenario (including treatment costs, taxes, etc.), costs are lower for CP implementation.

Table 17 Estimated cost analysis of production scenarios.

Costs per kg of finished product	Scenario 2007		Prospective Scenario	
	Without CP	With CP	Without CP	With CP
Pesos (C$)	14900	15800	16900	16400
Euros (€)	5,7	6,0	6,5	6,3

Once all expenses not currently included are integrated into the production process such as taxes, water supply, waste treatment (primary and secondary), dangerous waste disposal, legal counseling and fines, CP results will be more profitable in all cases. Nevertheless, it is essential to improve final product quality in order to achieve a higher sales process and market share.

Prices for the final product depend on type of leather. Market prices for liner leather ranges from 1,24€[7] to 2 € per m^2. Tula type leathers run between 2,2 € and 2,5 € per m^{2}[(8)]. Breakpoint value for the prospective scenario with CP is 2,1€ per m^2, which is well inside the current price range (Oral communication in 2007).

5.4. Role of law and law enforcement in performance improvements

The application of environmental regulation has been hardly accepted by the tanner community. With CCB support, 66 factories adopted EMP (Sanz, 2007). But legal problems faced by tanneries are still awaiting a solution. Most tanneries are immersed in suits due to pollution loads, which would make them subject to high fines.

CP is expected to be included in environmental regulations as an integrated strategy, in a way that motivates compliance with environmental improvement norms. In the past, pressure from regulatory bodies was influential in erecting treatment systems in workshops.

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[7] Exchange rate 2614.5 pesos for 1 euro. Revista Portafolio, 25 de junio de 2007
[8] Each skin measures approximately 13 m^2

Through CP implementation it is expected that tanneries will be legally established as formal companies, with full regulatory compliance and ending legal procedures currently running. This will improve their competitiveness by means of better product quality and access to new markets.

5.5. Role of stakeholders in performance improvements

In a previous paper, where cooperation from the parties involved in the tanneries' conflict is sought (D 4.2.2), the need was found for a strategy to make understandable to authorities (Procuraduria, CAR) that a sustainable solution for the river's pollution cannot be just to close tanneries (Sanz, 2007 b). Additionally, this paper identifies the alliances between institutions and the associative work as essential factors in the process of change.

It is necessary to identify the main allies for the tanner community from among the different actors for the improvement process according to the interests of each actor. In the framework of the definition of the solution strategy, which includes a successful CP strategy implementation and their roles, following stakeholders were identified as allies:

- **Small size tanners:** interested in cleaning the river, as long as their rights are preserved and their needs attended to. They must educate themselves in cleaner procedures for tanning, treatment systems and to improve product quality. They must be trained in conflict resolution, improving their relationships with institutions and must legalize their work status situation.
- **Authorities (CAR– Procuraduría):** With the help of other government agencies, they can become allies. Open communication channels and the presence of academics are essential for a longer alliance. In this way, CP can be an option for organisms oriented to end-of--pipe solutions.
- **Other possible allies**: Office of the Presidency of Colombian, political circles, Ministries (related to tanneries sector), provincial government and justice. Lawyers, commercial institutions supporting micro businesses, local powers, other successful cases of CP implementation, local and international academies and financial institutions (Sanz, 2007b).

5.6. Comparative analysis of the tanneries' situation with and without performance improvements

The tanneries' current situation is absolutely unsustainable, as the very high costs associated with final disposal will not permit any profitability. Micro tanneries must commit themselves to CP implementation as a survival strategy.

Micro tanneries gain sustainable development in every level (technical, social, financial, commercial), through adopting CP. They have the opportunity to ameliorate their environmental qualification, improve their product quality, to increase their market status and to actively lead change processes.
Through improved technical procedures, water and energy consumption is reduced, waste water quality will be acceptable to be discharge into the river and the quality of final product will increase, thus generating, benefits at the economic, social and commercial levels.

6. Conclusions

- Improving the tanning industry requires owners' commitment, a systematic approach to reduce and prevent pollution from every operation in the production process and an adequate use of human, technical and environmental resources.

- Villapinzon tanneries are, in most cases, informal and traditional establishments where the production processes are transmitted verbally from one generation to the next. In this case study, mainly human factors made introducing process changes difficult.

- Process monitoring (production registers, indicators, and cost analysis) is not existent in the industries of this area. CP strategy implementation demands, therefore, a change in attitudes and uses, by strengthening best operational practices and basic process improvements. These two alternatives are a basis of the implementation of new and advanced technologies.

- Most of wastes can be integrated to the leather productive chain to give it value and generating profit for the industry. Currently its management is unsustainable because there are no clear solutions to the waste disposition in the region. Thus, it's important to integrate this with the associative component to achieve disposing and giving value to these wastes in group form.

- Technical and technological solutions, as those presented in this study, oriented to obtain better environmental quality, must be jointly worked out with action in association and institutional relationships. This is a consequence of the observed fact that a change in individual behavior generates greater impacts than technological changes.

- CP implementation needs that the tanners become owners of the process of change. It is necessary to speed up and strengthening the interinstitutional work. In this way the integration of the components of CP will be reached and this strategy will be part of the decision making process.

- The regulation cannot be a constraint in the improvement process. The approach must to be changed from the sanction-oriented one currently in use, to one of continuously "walking with" industries, as well as giving CP a normative frame, going beyond a willingness agreement.

- From the analysis of expected benefits of implementing CP in the Villapinzon tanneries, it can be concluded that the project will be in the path of the paradigm change that SWITCH drives, consisting in a better use of water in accordance with required water quality conditions. In the same path, with simple techniques water use would be significantly reduced and the river's water quality would be greatly improved, as well as social and economic benefits accrued. The environmental solution in this framework is not based on technological breakthroughs, but in an acceptance of changes in the way water as a resource is perceived and consumed, in order to achieve its better use.

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