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Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

# D 4.2.4: Field testing CP options in micro-industries of Villapinzón and Chocontá

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| Audience<br><br>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. |
| Purpose<br><br>The goal of this research is to contribute to the Bogota River integrated management and to the sustainability of micro-tanneries.<br><br>The research objectives are:<br>o To present the main results of the CP implementation,<br>o To carry out a follow-up of CP implementation<br>o To monitor the implementation of an integrated and optimal solution to the environmental, social and economic problems of the tanneries. |
| Background<br><br>The leather production process has had, for decades, a highly negative environmental impact caused by inefficiencies in production operations. The conventional process used huge volumes of water, energy and chemical inputs. The resulting solid and liquid wastes and effluents were discharged onto the Bogotá River without any treatment.<br><br>Due to the high negative environmental impact of the tanning activity, a preventive strategy for pollution management has been required in the region in order to reduce this impact. This strategy cannot be just a final and regular control strategy, better known as an end-of-pipe alternative. It has to include improvements in the whole process to reduce the pollution loads and also the wastewater volume to be treated and related costs.<br><br>In addition, it is required a system monitoring structure to monitor the progress of the tanneries towards sustainable development. It implies a new way of thinking and analyzing current development levels in society. It is grounded in environmental, economic and social considerations, emphasizing topics not considered in traditional development models and affecting government policies, consumption patterns and the context of competition in production sectors (Van Hoof *et al.*, 2008; Maya, 1996; Maya, 2000). The main purpose of the assessment is to support the Villapinzón and Chocontá tanning process stakeholders in planning and decision making. |
| Potential Impact<br><br>The process of CP implementation in some tanneries of Villapinzón and Chocontá has |

shown a high variation in terms of performance, pollution and solid wastes. This kind of variation is typical of the tanning process and it has been represented in the deviations presented in the diagnosis phase. Some cleaner technologies has been followed up achieving significant reduction ranges in the chemicals consumption (sodium sulphide (10 – 57%), ammonium sulphate (11%), chromium sulphate (1- 32%)) and in the pollutant loads (Unhairing: BOD (33 – 77%), Sulphides (72 – 87%); Deliming: TKN (27- 99%); Tanning: Chromium (52 – 94%)). In water consumption the reduction may vary between 17 and 68% depending on the operation of the process. These reductions imply that a percentage of a pollution discharge is avoided with preventive measures implemented in the operations through the time. The participation of the community has been decisive in all the process.

In the monitoring system, the environmental, social and economic indexes integrated in the sustainable development index have shown gradual progress in the sector. The environmental conflict of years back has generated an interest in progressing towards the development of a stronger sector, one more organized, making their own the process of the transformation from the environmental, social and economic spheres. Additionally, the gradual increase of this index indicates that the comprehensive efforts towards the improvement in all dimensions must be continuously reinforced.

These positive results in a small sample of tanneries should impact the entire community of tanners in this region and in the whole country. This kind of improvement process need to be implemented in all these industrial communities, overall, the communities of micro enterprises that face particular problems and challenges due to their limitations in labor quality, technical and financial resources. The active participation of the community during the entire process is essential to create sustainable strategies to the environmental and social conflicts.

However, in order to implement CP over the long term, all the efforts done will be really useful if there is an appropriate institutional framework to back it, if land and environmental issues complement each other and if the CP is included in the environmental regulation in a way that motivates compliance with environmental improvement norms.

## Recommendations

- It is important to establish economic incentives for environmental improvements so that the change process can be assured and the cleaner production is thus viewed by the tanners as a cost-benefit process.

- With the aim of making the tanning activity a sustainable one, it is necessary to grant continuity to the improvements in all dimensions. The work on cleaner production and in the prevention of contamination must be continued as well as the work in strengthening the social capital, access to spaces of participation, the collective participation in the generation of new strategies, the galvanization of the market, increasing the quality of the products and accessing new markets.

**D4.2.4-a A report presenting the selected impact reduction options per site of implementation**

**D4.2.4-b A report describing the monitoring scheme for the duration of the field testing program**

**D4.2.4-c A report on the actual implementation and monitoring of performance i.e. achieved emission reduction benefits relative to the cost of implementation**

# D 4.2.4 Field testing CP options in micro-industries of Villapinzón and Chocontá

# D 4.2.4 Field testing CP options in micro-industries of Villapinzón and Chocontá

## 1. Introduction

The tanning industry takes advantage of a high quantity of by-product from the cattle sector in the form of animal skin. Tanneries in Colombia have an economic importance of their own, as they absorb significant amounts of labor and have an "export vocation" (CCB, 2004).Tanneries are mostly located in Cundinamarca (82%), Nariño (10%) and Quindío (4%) departments (the Colombian equivalent to provinces) given the number of units. This kind of micro-industries is characterized by low technical and technological development, handcrafted production processes, deficient infrastructure, uncontrolled discharging of waste into rivers (Alzate, 2008) and high contaminants' load discharges in water and soil.

Tanneries in Villapinzón and Chocontá, both towns of Cundinamarca, have strongly degraded the water quality in the Bogotá River (DNP, 2004), as wastes are discharged with little or no treatment at all, resulting in high values of polluting load in the river, well above those maximum limits allowed by environmental regulations (CCB, 2004). The environmental problems of the tanneries have worsened by people's rejection of their activity specifically due to solid waste dumping in open spaces (Sanz, 2010). Their individualistic culture and the high number of units have prevented them from working together in search of associative solutions to environmental and productivity issues. In developing countries like Colombia, this kind of micro and small businesses have little negotiation power and their interests are put aside despite the fact that they represent 99,4% of the total number of enterprises (DNP, 2007). These industries entail complex problems (Sanz and Siebel, 2010).

In 2004, through a conflict resolution process headed by a PhD thesis from UNESCO-IHE, the Producer's Association -ACURTIR-, worked towards building internal empowerment positioning a new positive leader, setting an integral strategy with regard to strategic issues fighting social exclusion and a core end-of-pipe approach and building strategic alliances (Sanz and Siebel, 2010). At the end of 2004, with the support of the Centro Regional de Producción Más Limpia del Valle (Regional Center for Cleaner Production of Valle Department), they reached an agreement to start using environmental management technologies inspired on prevention. In particular, technologies based on CP were chosen, striving for the reduction of the negative environmental impact on the River's Upper Basin.

Furthermore, thanks to support from the Office of the Presidency of Colombia, the CCB (Bogota Chamber of Commerce) and ACURTIR jointly carried out environmental diagnoses and environmental management plans for the tanneries that were agreed to in cooperation with the environmental authority. After CCB finished the preparation of these plans, IDEA (Instituto de Estudios Ambientales), of Universidad Nacional de Colombia under the SWITCH Project "Sustainable water Management in tomorrow's cities health" started the current investigation in tanneries aiming to decrease the pollution generated by the tanning process. In 2007 and 2008, the environmental regional authority supported a project of training and technical advisory for the tanning sector. Since 2008, IDEA is supported by the environmental authority (CAR) and COLCIENCIAS, the Colombian Institute for Science and Technological Development, in order to strengthen the technical knowledge in CP, competitiveness and association building capabilities of tanneries committed to the project.

Developing these joint activities has resulted in the implementation of CP, establishing quality management systems and strengthening the tanneries' ability to associate and compete in the market. The main objective is to ensure the sustainability of these micro-industries. In order to

assess the impact of the cited projects, there is a need to monitor and to undertake a follow up of the progress achieved within the framework of sustainable development and cleaner production. Indexes and performance indicators have been established in order to monitor if the adopted strategies are improving tanneries' capabilities in CP, conflict resolution, competitiveness and productivity. The SWITCH group at IDEA jointly designed those parameters and designed a target to be achieved for each indicator.

An indicator system was established based on the Sustainable Development theory (Cuello & Durbin, 1995; Carpenter *et al.*, 2009). The system allowed evaluating the tanneries' sustainability by using the Sustainable Development Index (SDI). The indicators to be monitored were selected and typified, defining the data to be collected at each tannery. Twelve tanneries that were actively involved in the technical improvement process and committed to the joint work since the year 2004 were chosen to implement the selected indicators.

**Goal**

The goal of this research is to contribute to the Bogota River integrated management and to the sustainability of micro-tanneries.

**Objectives**

The research objectives are:

- To present the main results of the CP implementation,
- To carry out a follow-up of CP implementation
- To monitor the implementation of an integrated and optimal solution to the environmental, social and economic problems of the tanneries.

## 2. Background

### 2.1 Tanning sector in Villapinzón and Chocontá, Colombia

The Colombian tannery industry traditionally encompasses tanning know-how passed down through the generations. Colombia has eight tannery communities. The regional economy is characterized as being at a subsistence level, tanning technology is obsolete and the tanners have a primary level of education. Most of the factories are family businesses and employ from 4 to 6 workers. These families own the factories that 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 and Siebel, 2010).

The leather production process has had, for decades, a highly negative environmental impact caused by inefficiencies in production operations. The conventional process used huge volumes of water, energy and chemical inputs. The resulting solid and liquid wastes and effluents were discharged onto the Bogotá River without any treatment. The effluents usually contain high organic loads, suspended and dissolved solids, chloride, and sulphide, among other important pollutants. This industry is characterized by the foul odor that comes from the liberation of sulfhydric acid in the beamhouse stage and from the organic nature of the raw skin.

### 2.2 CP in the tanning industry

Due to the high negative environmental impact of the tanning activity, a preventive strategy for pollution management has been required in the region in order to reduce this impact. This strategy cannot be just a final and regular control strategy, better known as an end-of-pipe alternative. It

has to include improvements in the whole process to reduce the pollution loads and also the wastewater volume to be treated and related costs.

As an integral solution for the environmental, productive and socio-economic problematic in the tanning industry in Villapinzon and Choconta, and in accordance with the main concepts associated with cleaner production, CP has been assessed with respect to four components. These evaluation components were chosen in the framework of the principal five prevention points (USEPA, 1988; 1992; UNEP, 1994 cited in Van Berkel, 1999).

- Good operational practices (GOP)
- Chemicals' substitution
- Technological changes
- Reusing, recovering and recycling
- Product modifications

GOP makes reference to basic improvements with low investment costs. The implementation of the GOP is the first step if the tannery is planning to continue with new processing technologies and performance.

In the leather transformation process, chemical substitution is an important alternative in terms of efficiency, product quality and costs. Among the best available technologies (BAT) taken into account for the tanneries of the region, the substitution of chemicals is being implemented for the beamhouse stage (soaking and unhairing) and in the tanning stage (deliming). The environment cannot assimilate certain chemical substances; nevertheless, some receptor bodies assimilate these substances. An example is the chromium sediments in the Bogota River discharged by the tanning industry.

In the study region the changes in terms of technology have been in terms of the drums and the machinery. Some tanneries have replaced the conventional drums optimizing them for each operation. In this form, the operation is more effective because of the speed of the rotation of the drums, the effectiveness of the chemical inputs and the optimal timing and energy use. Due to these changes, a better quality in the final products can also be expected. Other changes are related to pumps and compressors for the different water uses.

Implementing reusing, recovering and recycling of effluents are not new technological options as the tanners have been using these in response to the deep crisis with the environmental authority. They began to develop these kind of strategies on the basis of their own experience. The technical controls to the operations (in terms of water and leather) are not the best in terms of technological options but water savings are achieved and the polluted discharges are reduced. All the above alternatives regarding the technological aspects have to be taken into consideration along with the social perception of the improvement of the tannery performance, quality of life and the economic aspect in cost benefit terms to be a sustainable alternative.

For CP implementation it is also essential to look towards improving the quality of the product or to develop a new final product. This gives dynamism to the activity and stimulates the owners to improve the enterprises performance, their products and their social image.

Finally, it's important to mention that in these kind of impacting activities, like tanning, it's not possible to meet the standards only with the preventive strategy because of the high pollutant loads, a product of the skins' organic nature, and the strong chemical needed to transform it. An end-of-pipe system is required but it must be optimized in terms of less quantity of wastewater produced and with less contaminant load, generating environmental and economic benefits from the source of the pollution.

### 2.3 System monitoring structure

The sustainable development approach (Donovan, Sadler & Bryson, 2005) has been a significant force in implementing environmental management systems that define strategies aiming at monitoring how changes in industrial practices affect the environment.

Colombia has adopted sustainable development as one that "leads to economic growth, improvements in the quality of life and social well being without depleting renewable resources for future generations" Art. 3º Law 99 of 1993.

However, sustainable development implies a new way of thinking and analyzing current development levels in society. It is grounded in environmental, economic and social considerations, emphasizing topics not considered in traditional development models and affecting government policies, consumption patterns and the context of competition in production sectors (Van Hoof *et al.*, 2008; Maya, 1996; Maya, 2000). The main purpose of the assessment is to support the Villapinzón and Chocontá tanning process stakeholders in planning and decision making.

The monitoring measures by means of defined indicators the changes made to the productive process at the technical, social and economic components, and determine the impacts of applying CP.

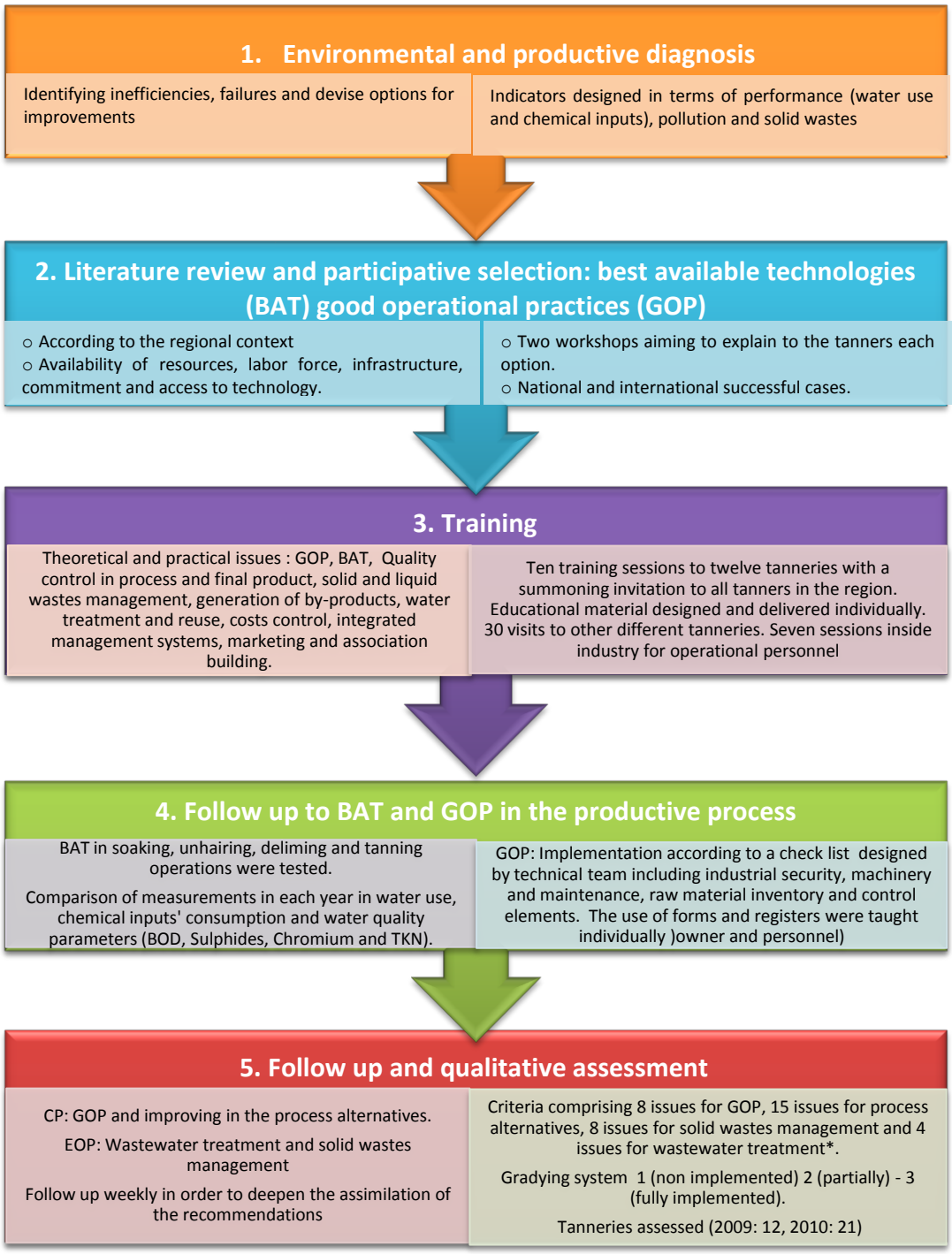
In the framework of sustainable development it is important to understand that the information generated to measure the progress towards sustainability of countries or of human activities is uncertain and many times of low quality due to the nature of the concept of sustainable development (CEPAL, 2009). Therefore, it has been considered of the utmost importance to define compound indicators that measure improvements or drawbacks and that can reflect the complexity involved.

According to the work of Nardo *et al.* (2005) in order to build compound indicators eight stages are necessary; development of conceptual frame; selection of indicators, multivariate analysis, imputation of missing data, normalization of data, weighting and aggregation, uncertainty, sensitivity analysis and visualization (Nardo *et al.,* 2005; CEPAL, 2009). This methodology can be adapted to the regional context, and to the availability of data. It can monitor the experience and the learning process through the knowledge transfer to other tanners of the region and to other tannery communities in the country.

## 3. Methodology

### 3.1 CP Implementation

During the research, the entire implementation process comprised five stages (Figure 1):




*The issues for component are presented in Table 1

**Figure 1 CP implementation methodology stages**

In Table 1, the components and issues of the follow up and qualitative assessment of CP in the tanneries are presented.

| COMPONENT | ISSUE |
|---|---|
| Good operational practices | Process standardization |
| | Order and cleanliness |
| | Chemical inputs |
| | Emergencies and accidents |
| | Protection personnel elements |
| | First aid kit |
| | Machinery and maintenance |
| | Control elements |
| Process alternatives | Preparation of skins in separate areas |
| | Reduction in the use of salted hides |
| | Shaking off and storage of salt |
| | Soaking with biodegradable products |
| | Hair recovery |
| | Reutilization and recirculation of water |
| | Quality control during the process and in final product |
| | Reduction in the use of ammonium salt |
| | Pickling with less content of salt |
| | High exhaustion of chromium |
| | Retanning with agents without chromium |
| | High exhaustion of dye |
| | Use of high quality greasing agents |
| | Effluents segregation after each operation |
| | Solid retention system and grease traps after drums |
| Solid wastes management | Separate storage |
| | Reduction in the source |
| | Separation during the process |
| | Hair composting |
| | Fleshing composting |
| | Valuation of solid wastes |
| | Marketing of wastes |
| | Treatment or disposition |
| Wastewater treatment | Water segregation, solid retention, sedimentation and grease traps. |
| | Flocculation, chromium precipitation, sulfide oxidation and homogenization |
| | Percolating filters |
| | Other technology for treatment |

**Table 1 Components and issues of qualitative assessment**

3.2 System monitoring structure

### 3.2.1 Data collection

In order to register the process in terms of the technical, social and economic components, some forms were designed by the technical team in order to evaluate each component at different points in time.

The forms related to the environmental dimension were structured according to the process stage in which the information was registered. All these forms were designed using a clear and easy to understand language in order to improve the adaptation of the tanners and the operational workers with respect to registering data on the field.

The economic form presents the cost structure to enable carrying out the cost-benefit analysis, not just at a specific moment, but in a permanent fashion, beginning with a system of quality

management at each enterprise. In addition to this form, another open interview was applied to qualify topics of intellectual property, business intelligence and product quality.

For information gathering regarding social aspects, an interview was structured to be carried out with technicians and the owners of the tanneries.

### 3.2.2 Structure

The structure of the monitoring system is based on three specific objectives, each one of them focusing on achieving sustainability in the tanning industrial sector. The monitoring system, in accordance with the three specific objectives mentioned above comprises three interrelated dimensions which are: environmental, social and economic. This structure is presented in Table 2.

| Dimension | Objective and observations | Categories |
|---|---|---|
| Environmental | *To decrease pollution*<br>Lowering waste dumping volumes and improving production methods in order to reduce and prevent polluting loads dumped onto the Bogotá River | ○ *Performance:* measures water and chemical consumption (essentially sulfides and chromium salts) during the production processes.<br>○ *Pollution*: each one of the control parameters is measured in waste streams or in the final discharge along the tanning process.<br>○ *Solid wastes:* those generated by the production process. |
| Social | *To increase association building capabilities*<br>Micro and small sized enterprises must associate in order to face up to global competition. The system evaluates the behavioral changes of the tanners, the structure and performance of the associations, and cooperation networks in the tanning sector. | *Social capital:* factors that describe, and anticipate behavioral changes in terms of the quality and access to participation, in determining the progress, if any, in the quality of the relationship between stakeholders and finally recognizing if there is a consensus in relation to the perceived definition of the problems.<br>*Wellbeing:* An analysis to ascertain that after implementing CP, financial resources are still available to assure a proper living standard among the tanners.<br>*Legal Commitments:* This criterion contains three variables that allow evaluating the legal and environmental compliance of the tanneries. |
| Economic | *To increase competitiveness*<br>At an economic level, the system is oriented to show the effectiveness of changes in managerial and production processes in order to obtain productivity and profitability improvements, without deteriorating the quality of the natural resources used by the tanneries. | The following are the selected criteria for measuring the economic dimension:<br>*Economic Performance:* it allows a measure of managerial effectiveness based on unit variable costs and by-products´ added value.<br>*Innovation and Satisfaction:* a measure of how the final consumer needs are being fulfilled by the tanneries' products and services. |

**Table 2 System monitoring structure**

### 3.2.3 System of indexes and indicators

Adapting the methodology of Nardo *et al.* 2005 to the regional context and the availability of data the stages presented in the building of the set of indexes and indicators are presented in Figure 2. The system develops indexes and indicators based on currently accepted methodologies (Jorgensen *et.al*., 1996; United Nations, 2007; CEPAL, 2009).

In the methodology framework defined by the United Nations in 2009 (CEPAL, 2009) and respect to the index of environmental performance developed by Yale University in 2008 a target was defined for each indicator to measure, at different moments of the project the efforts of the tanneries in terms of environmental protection and prevention of pollution and finally how far the tanneries are of each target defined in each dimension. These indicators and targets were designed and validated by the members of the whole equipment of IDEA, the stakeholders involved and the tanners. All the information gathered in the process through the registry forms (production registries, interviews with stakeholders, etc.) was linked to each indicator.

All the data gathered on the field are incorporated in the system of indicators in order to undertake a compilation of the data in a computational package, to calculate indexes, carry out comparisons between tanneries, and measure changes in each indicator.

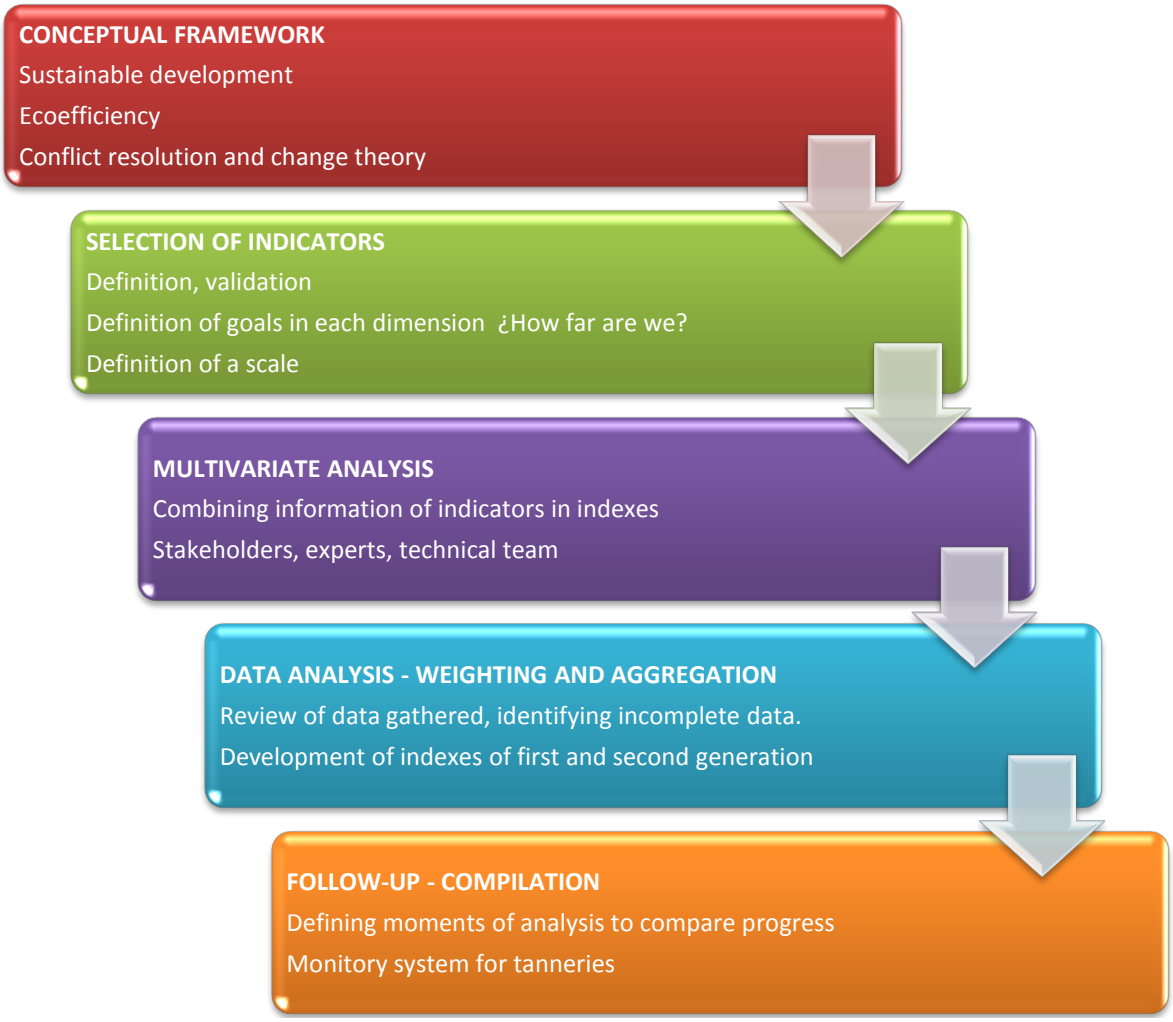



**Figure 2 Methodology of the definition of the indicators and structure of monitoring**

In figure 3, the structure of the indexes and indicators is shown, with the formula used to calculate each value indicating the weight given to each index. The index of sustainable development

measures the advance of CP process in terms of sustainability in the tanning sector. It is calculated from three separate indexes, each one reflecting one of the dimensions comprised by the sustainable development concept, that is, environmental, social and economic.

The environmental index's components signal the degree to which every resource used as an input in the tanning process is adequately used and disposed of after finishing production. It was considered that the consumption of inputs, the quality of effluents and the solid waste management have the same impact on the environmental performance of the tanneries. Social processes are developed prior to and are transversal to any activity (economic or environmental). The social indexes must be interpreted as being the leading variables for every other process undertaken.

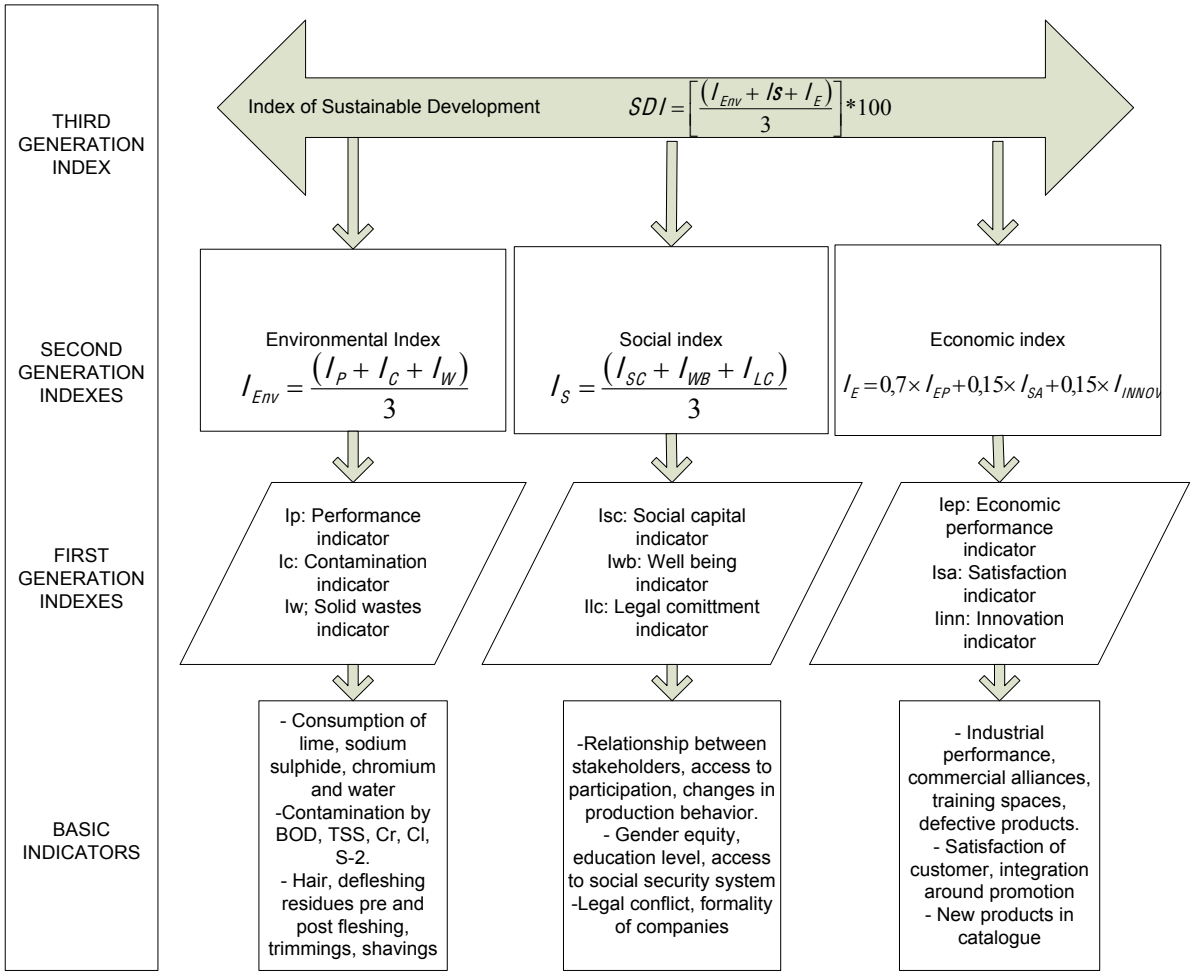



**Figure 3 Structure of the indicators and indexes system**

In Table 3, the metadata of each basic indicator is shown, indicating the unit of measure and the methodology used in each dimension.

| Index | | Indicator | Unit | Methodology |
|---|---|---|---|---|
| ENVIRONMENTAL INDEX | Performance index | Sodium sulphide | Kg/ton skin | Measuring the weight of each chemical input |
| | | Lime | Kg/ton skin | |
| | | Chromium salt | Kg/ton skin | |
| | | Consumed water | $m^3$/ton skin | Evaluating water flow in the entry of the drums |
| | Pollution index | BOD load | Kg/ton skin | Taking samples from discharged water and laboratory analysis |
| | | Sulphide load | Kg/ton skin | |
| | | Total suspended solids load | Kg/ton skin | |
| | | Chromium load | Kg/ton skin | |
| | | Chloride load | Kg/ton skin | |
| | Solid wastes index | Hair | Kg/ton skin | Filtering unhairing effluent, storing and weighting. |
| | | Defleshing wastes pre and post defleshing | Kg/ton skin | Collecting the waste, storing and weighting. |
| | | Shavings | Kg/ton skin | |
| | | Trimmings | Kg/ton skin | |
| SOCIAL INDEX | Social Capital index | Access to participation | Qualitative: Never, sometimes, always Participation in scheduled meetings and on decision making | Direct interviews |
| | | Nature of relationship among stakeholders | Friendly, strained, aggressive. | Direct interviews |
| | | Changes in production behavior | Participation of the tanneries in the improvement processes | Direct interviews |
| | Well being index | Gender Equality | Average salary of women Average salary of men | Direct interviews |
| | | Education Level | Qualitative (primary and secondary education) | Direct interviews |
| | | Social Security System Access | # Employees member of the professional risks association and the pension and health. | Direct interviews |
| | Legal commitment index | Legal Conflict | # of valid processes, # of expired processes | Direct interviews |
| | | Business Formality | # of formal enterprises (register in CCB, accounting, CAR permissions) | Direct interviews |
| ECONOMIC INDEX | Economic Performance Index | Costs system: Final prize per decimeter of final product, Cost of chemical inputs Quality and innovation level | Percentage | Follow up form of the productive process. Direct interviews |
| | Customer Satisfaction Index | Processes management. Bottlenecks Defective products Commercialized products Complaints due to poor quality | Absolute value | Direct interviews and field visit |
| | Innovation Index | New products Existing products | Absolute value | Direct interviews and field visit |

**Table 3 Metadata of indicators**

## 4. Results

### 4.1 Cleaner production implementation

#### 4.1.1 Environmental and productive diagnosis

Tables 4 to 6 show arithmetic average, standard deviation and maximum and minimum values in performance, pollution and solid wastes indicators corresponding to the results of the diagnosis for twelve micro-tanneries. With respect to pollution indicators, the results are shown for two groups: the first group of 4 tanneries that had built by 2008 the physicochemical treatment and one tannery whose system was in stabilization period and the second group of 8 tanneries that had not built the physicochemical treatment by this year. This fact does not affect the performance or the solid wastes indicators.

| Performance indicators (kg-m$^3$)/T) (N=12)* | Average | SD | Max | Min |
|---|---|---|---|---|
| Sodium sulphide | 9.05 | 3.13 | 15.75 | 3.61 |
| Lime | 51.74 | 17.20 | 75.68 | 23.47 |
| Chromium salt | 39.18 | 13.26 | 65.56 | 21.66 |
| Water | 12.39 | 6.79 | 28.18 | 4.35 |

*The parenthesis shows the sample size (N)

**Table 4 Performance indicators in twelve micro-tanneries**

| WITH PHYSICOCHEMICAL TREATMENT (N=4)* | | | | |
|---|---|---|---|---|
| Pollution indicators (kg/ton) | Average | SD | Max | Min |
| BOD | 6.08 | 10.35 | 21.57 | 0.22 |
| Chromium | 0.64 | 1.27 | 2.55 | 0.00 |
| TKN | 1.43 | 2.04 | 4.41 | 0.08 |
| Chlorides | 36.13 | 58.46 | 123.64 | 4.11 |
| Sulphide | 0.33 | 0.65 | 1.30 | 0.00 |
| TSS | 8.70 | 17.10 | 34.34 | 0.01 |
| WITHOUT PHYSICOCHEMICAL TREATMENT (N=8)* | | | | |
| Pollution indicators (kg/ton) | Average | SD | Max | Min |
| BOD | 43.69 | 26.83 | 89.25 | 12.24 |
| Chromium | 1.16 | 2.19 | 6.51 | 0.00 |
| TKN | 4.26 | 3.99 | 10.32 | 0.53 |
| Chlorides | 62.55 | 48.39 | 134.10 | 5.87 |
| Sulphide | 4.88 | 3.86 | 12.77 | 0.39 |
| TSS | 25.31 | 18.58 | 64.60 | 2.45 |

*The parenthesis shows the sample size (N)

**Table 5 Pollution indicators in micro-tanneries with and without physicochemical treatment**

| Solid wastes indicators (kg/ton) (N=12)* | Average | SD | Max | Min |
|---|---|---|---|---|
| Unhairing wastes | 129.46 | 49.81 | 199.38 | 43.32 |
| Defleshing wastes | 289.26 | 113.33 | 385.80 | 43.92 |
| Shaving wastes | 125.63 | 92.29 | 297.98 | 21.00 |
| Leather trimming | 24.13 | 8.85 | 37.84 | 12.30 |

*The parenthesis show the sample size (N)

**Table 6 Solid wastes indicators in micro-tanneries**

### 4.1.2 Literature review and selection of BAT and GOP

Table 7 shows the selection made after a literature review regarding BAT and GOP for tanneries. The selection had a strong participative component taking into account the current situation of the tanners in terms of their technical and economic resources. The following BAT and GOP, to be implemented in their micro-industries, were selected in two workshops with the tanners.

| | |
|---|---|
| **BAT** | Soaking with biodegradable products |
| | Ecologic unhairing with hair immunization |
| | Unhairing bath recycling |
| | Deliming with nitrogen free products |
| | High chromium exhaustion |
| **GOP** | Processes standardization |
| | Order and cleanliness |
| | Water reuses |
| | Chemical inputs handling |
| | Emergencies and accidents |
| | Personal protection elements |
| | First aid kit |
| | Machinery maintenance |
| | Control elements |

**Table 7 BAT and GOP selected to be implemented in micro-tanneries**

### 4.1.3 Training

- Theoretical and practical issues were included in the training sessions: GOP, BAT, control process, industrial safety, solid wastes management, cost control, marketing and association building.
- Ten training sessions were held for tanners of the region including learning from other tanners' experiences with a summoning invitation to all tanners of the region.
- Tanners from Bogota, El Cerrito (Valle del Cauca Province, Western region of Colombia) and Bucaramanga, presented their results on solid and liquid waste management, process control and highly relevant for the audience, on their relationship with their regional environmental authority (CVC) and their corresponding legal framework and association building capability improvement.

Training session: Jar Testing

Development of new products. Retanning

- Educational material was designed, delivered and explained to the tanners in the training sessions (CP Guides for tanners, flowchart of the process stages integrating production and control registers).

- 30 site visits were made to other tanneries to provide an introduction about CP.
- Seven training sessions were carried out inside each of the pilot industries especially for operational personnel and the owners of the factory using the educational material previously designed.
- Through learning alliances with the Technological Center for the Industries of Leather, Footwear and similar (CEINNOVA by its Spanish acronym) a complete training module about leather quality and new products was provided to the tanners in 2009.
- The sessions (theoretical and practical) were carried out with the participation of national experts in leather production, and workers and experts in quality leather tests of the CEINNOVA center. These experts were present in practical sessions geared towards improving product quality through the use of less contaminating alternatives.

Training in leather quality (CEINNOVA expert)

Training session with tanners of El Cerrito - Valle

### 4.1.4 Follow up to BAT and GOP in the productive process

Some cleaner technologies were tested in productive process for three tanneries making a follow up for three years (2004, 2008 and 2009). The follow up was made for four operations of the tanning productive process: Soaking, unhairing, deliming and tanning. Other punctual experiments were made in unhairing and deliming with chemical suppliers. The information for obtaining the data for 2004 was gathered from the environmental management plans made by the Chamber of Commerce of Bogotá in this year.

In the following figures (4 – 10), the main parameters of each operation are shown in the different moments of analysis. The reductions of each parameter imply that a percentage of a pollution discharge is avoided with preventive measures implemented in the operations through the time. In the table 8, the reductions are shown for each operation as a range between the three tanneries analyzed.

*Soaking:*

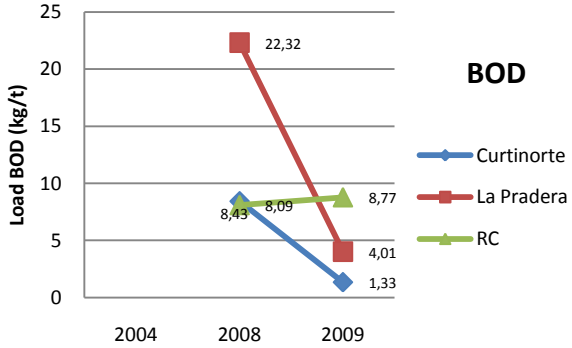



**Figure 4 BOD in soaking operation**

*Unhairing:*

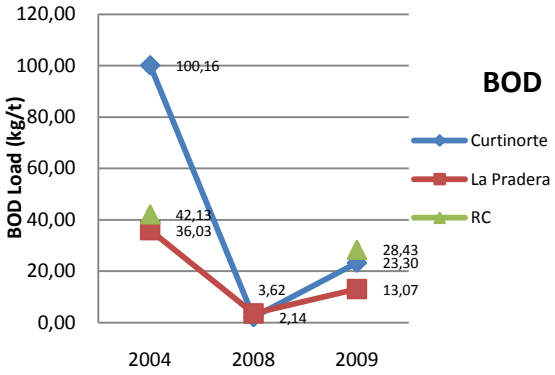



**Figure 5 BOD in unhairing operation**

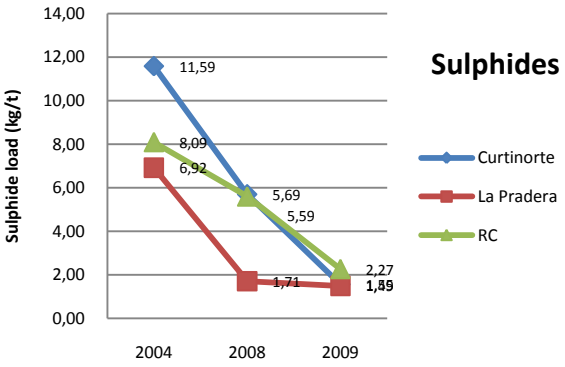



**Figure 6 Sulphides in unhairing operation**

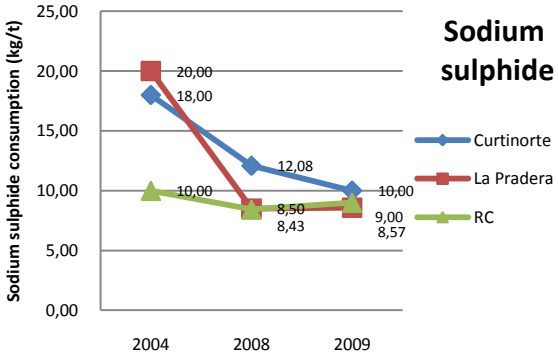



**Figure 7 Sodium sulphide consumption in unhairing operation**

*Deliming:*

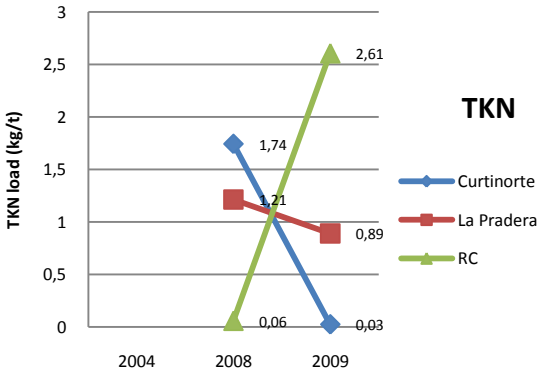



**Figure 8 TKN load in deliming operation**

*Tanning:*

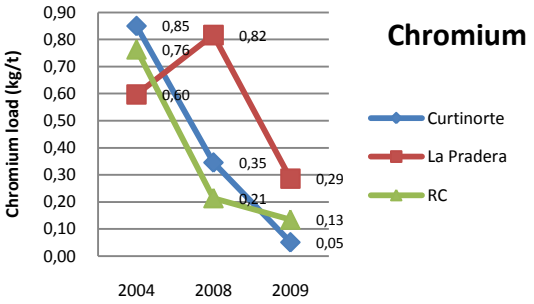



**Figure 9 Chromium load in tanning operation**

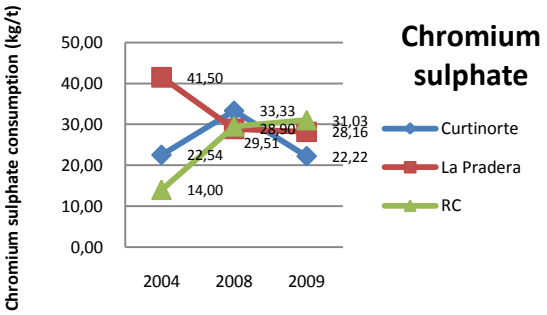



**Figure 10 Chromium sulphate in tanning operation**

| OPERATION* (N=3) | PARAMETER | % REDUCTION |
|---|---|---|
| Soaking (2008 - 2009) | BOD** | (8) - 84 |
| Unhairing (2004 - 2009) | BOD | 33 - 77 |
| | SST | 79 - 98 |
| | Sulphides | 72 - 87 |
| | Sodium sulphide | 10 - 57 |
| | Lime | 11 - 53 |
| Deliming (2008-2009) | TKN | 27 - 99 |
| | Ammonium sulphate*** | 11 |
| Tanning (2004 - 2009) | Chromium | 52 - 94 |
| | Chromium sulphate | 1 - 32 |

*The parentheses show the period in which the reductions were calculated. N is the sample size
**The number between parentheses indicates one tannery that did not achieve reduction in BOD
*** In deliming, only one tannery had availability of registers to calculate the ammonium sulphate reduction

**Table 8 Reductions percentages in tanning process**

The reduction percentage in the water consumption is shown in the Table 9. In the Figure 11 the average consumption for each year is also observed.

| **Operation (N=3)*** | **2004** | | **2008** | | **2009** | | **% REDUCTION** | |
|---|---|---|---|---|---|---|---|---|
| | **Average** | **SD** | **Average** | **SD** | **Average** | **SD** | **2004 - 2008** | **2004-2009** |
| Soaking | 2,27 | 0,46 | 2,13 | 1,28 | 1,83 | 1,17 | 6% | **19%** |
| Unhairing | 2,86 | 0,66 | 2,34 | 1,79 | 1,65 | 0,45 | 18% | **42%** |
| Deliming | 0,78 | 0,41 | 0,73 | 0,53 | 0,64 | 0,16 | 6% | **17%** |
| Tanning | 0,95 | 0,39 | 0,64 | 0,60 | 0,30 | 0,05 | 32% | **68%** |

***N is the sample size**

**Table 9 Water consumption average in tanning productive process**

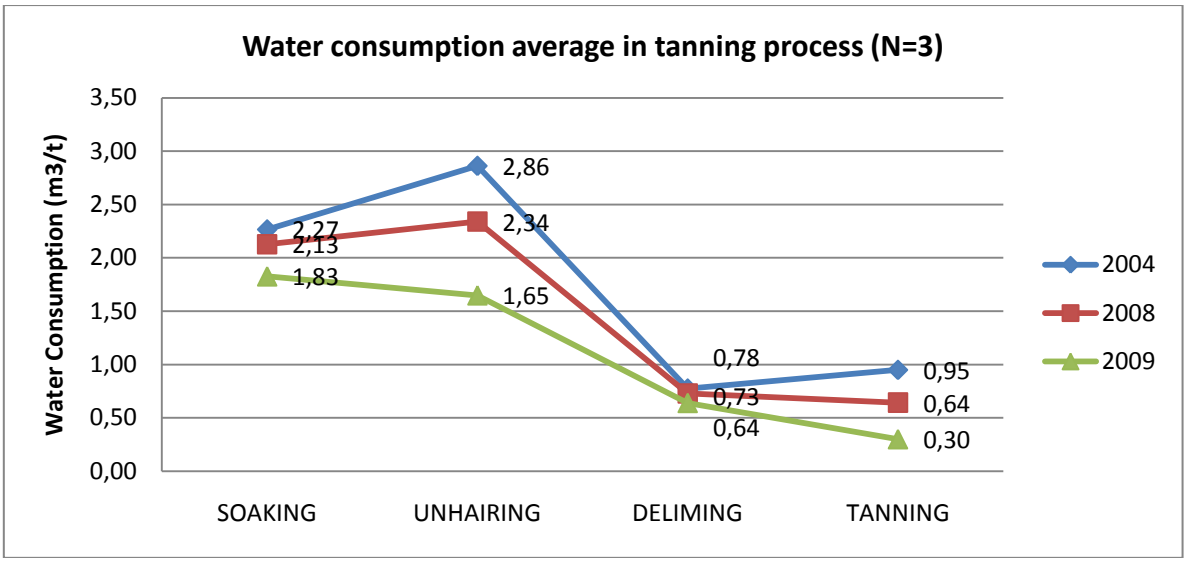



**Figure 11 Water consumption average in tanning production process (N is the sample size)**

In Table 10 the results of an interview are presented in terms of the number of tanneries implementing each alternative.

| **Cleaner Technology** | **Total interviews: 20 tanneries** | **OBSERVATION** |
|---|---|---|
| Good operating practices | 20 | 12 tanneries have begun the process standardization. 2 tanneries have made significant progress. 8 tanneries do not control the process. |
| Salt recovery | 15 | The shaking is manual. 3 tanneries use fresh skin. 2 tanneries do not shake the skins. |
| Addition of biodegradable bactericides and surfactants | 15 | The overall chemical nature of each chemical input group depends on the supplier. |
| Ecologic Unhairing with hair Immunization | 18 | Two tanneries do not perfom this operation. The first input is wetblue. |
| Unhairing bath recycling | 18 | It has been a common practice since last years. More technical controls are needed and operative personnel need to be trained. |
| Deliming with nitrogen free products | 3 | In the market there are good quality products. The cost is high. |
| High chromium exhaustion | 16 | All these tanneries made a good quality control (pH). Two of them use exhausted agents and only one controls the temperature to make absorption of chromium in the skin efficient. |

**Table 10 Number of tanneries implementing CP**

### 4.1.5 Follow up and qualitative assessment

The qualitative assessment carried out in 2009 and in 2010 carried out the follow up of the issues shown in Table 1 for each component: GOP, process alternatives, solid waste management, and wastewater treatment. Figure 12 shows the results of this assessment, presenting an overall increase in the implementation of process alternatives and GOP. The scores obtained in 2009 show that the GOP and wastewater treatment are the most implemented components. In 2010, the

highest scores correspond to GOP and process alternatives. All four components show increased scores.

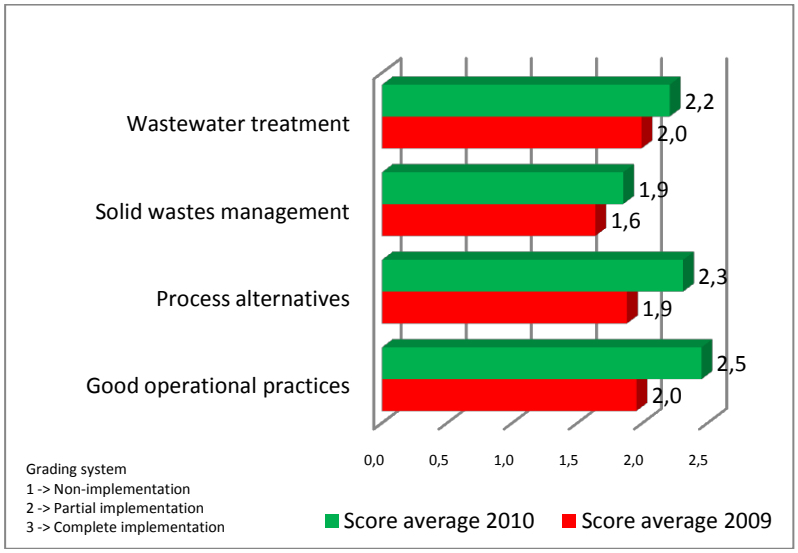



**Figure 12 Assessment in CP and EOP for twelve tanneries**

- It is important to make emphasis in the reuse of unhairing baths and the ecological unhairing. These alternatives have been new process technologies applied by some tanners since 2005. These implementations do not have the strict technical control needed.
- In this follow up, changes introduced by the tanners experience were also followed.
- Some reuses in tanning baths have been tested by some tanners. In the region, only the industries that transform split leather reuse around 40% of tanning baths without treatment.
- Some cleaner strategies were known by the tanners, unless for the technical controls and main benefits. Nevertheless, tanners do not have the technical and chemical knowledge needed to determine quantities and times without affecting the product quality.
- Since 2008, the tanneries used to reuse the unhairing and liming baths of one batch as the entry water of the next one storing the first bath in a conical tank.
- Samples had been taken in two stages (2008 and 2010) of these baths to monitoring this strategy and research work was carried out specifically with respect to the effect of the reuse in the product quality.
- One research thesis was carried out in the reuse of unhairing baths to evaluate the effect of the reused baths in the quality of the final leather.

### 4.2 System monitoring structure

*Conceptual framework*

Three principles compose the conceptual framework of the monitoring system;

(1) Sustainable development, in which three dimensions of the development has to be measured (environmental, social and economic),

(2) Eco-efficiency in which the performance of the microenterprises has to be directed to the environmental and productive efficiency,

(3) Conflict resolution and change theory, in which the conflict is seen as a positive element and must be seen as an opportunity.

*Selection of indicators and definition of targets*

After defining the conceptual framework of the composite indicators, the indicators were selected and validated by stakeholders, experts and technical team and a target according to each indicator in environmental, social and economic dimension was defined.

The measurement range defined to assess the progress is 0 – 1, in which 0 means that the tannery is far away from the target defined and 1 means the complete fulfillment of the target. With this range, all indexes are in the same scale and operations among indexes of each dimension can be made.

In terms of these targets, in the environmental dimension, the literature offer certain values depending on the category: for performance, optimal and wide ranges for consumption of chemicals and water are found (UNEP, 1994 and communication by experts), for pollution, the target for achieving sustainability must be the current regulation to final discharges (regional regulation) and for solid wastes, different ranges and values are found depending of the kind of process carried out (UNEP, 1994; Fendrup, 2000; FAO and UNIDO, 2000; MAVDT, 2006). Table 9 shows the environmental targets. In the other dimensions (social, economic) a target of 1 was defined for all the indicators by agreement between the tanners and the technical team.

*Aggregation and definition of moments of analysis*
Three different moments of analysis were defined to measure the progress of the tanneries in terms of sustainable development with the aggregation of the indexes in each dimension; environmental, social and economic. The first moment (1) corresponds to the moment in which the project begins in the year 2004. The second moment (2) is the year 2008 in which the process of CP implementation begins with the environmental diagnosis of the tanneries. The third moment (3) corresponds to the information gathered in 2009 and 2010 in which the process of CP implementation is being followed up.

### 4.2.1 Environmental dimension

To measure the efforts of the tanneries in order to make tanning a sustainable activity, some targets were defined for each indicator in a scale of 0 – 1. The targets for each basic indicator are shown in Table 11.

| First generation index | Basic Indicator | Target (kg/ton) | Reference |
|---|---|---|---|
| Performance | Sodium sulphide | 30 | UNEP, 1994; Buljan *et al.*, 2000; Nazer *et al.*, 2006, European Comission, 2009 |
| | Lime | 45 | |
| | Chromium salt | 50 - 60 | |
| | Water | 12 - 37 | IUE, 2008; European Comission, 2009 |
| Pollution | Organic load | 4,9 | CAR, 2006 |
| | Chromium load | 0,000245 | CAR, 2006 |
| | Chlorides load | 6,1 | CAR, 2006 |
| | Sulphide load | 0,0245 | CAR, 2006 |
| | TSS load | 24,5 | CAR, 2006 |
| Solid wastes | Unhairing wastes | 100 - 150 | Fendrup, 2000 |
| | Defleshing wastes before unhairing | 100 - 150 | MAVDT, 2006 |
| | Defleshing wastes after unhairing | 120 | UNEP, 1994; Verheijen *et al.,* 1996; Buljan *et al.*, 2000 |
| | Shavings wastes | 99 | UNEP, 1994; Buljan *et al.*, 2000 |
| | Trimmings | 10 | UNEP, 1994; Verheijen *et al.,* 1996; Buljan *et al.*, 2000 |

**Table 11 Targets defined in environmental dimension**

In Table 12, the results of each component of environmental index are shown for each tannery.

| INDEXES | Performance | | | Pollution | | | Solid wastes | | |
|---|---|---|---|---|---|---|---|---|---|
| Moment | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| C1 | 0,99 | 1,00 | 1,00 | 0,00 | 0,80 | 0,87 | 0,45 | 0,31 | 0,31 |
| C2 | 1,00 | 1,00 | 1,00 | 0,18 | 0,20 | 0,07 | 0,14 | 0,89 | 0,13 |
| C3 | 0,94 | 0,90 | 1,00 | 0,00 | 0,18 | 0,80 | 0,27 | 0,45 | 0,38 |
| C4 | 0,89 | 1,00 | 1,00 | 0,00 | 0,37 | 0,40 | 0,33 | 0,48 | 0,53 |
| C5 | 1,00 | --- | 1,00 | 0,00 | --- | 0,20 | 0,24 | --- | 0,24 |
| C6 | 1,00 | 0,94 | --- | 0,00 | 0,20 | --- | 0,24 | 0,61 | --- |
| Average | 0,97 | 0,97 | 1,00 | 0,03 | 0,35 | 0,47 | 0,28 | 0,55 | 0,32 |
| SD | 0,05 | 0,05 | 0,00 | 0,07 | 0,26 | 0,36 | 0,10 | 0,22 | 0,15 |

**Table 12 First generation indexes for each tannery**

The final result for the indexes of first and second generation is shown in Table 13.

| Index | Moments of analysis | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Performance | 0,97 | 0,97 | 1,00 |
| Contamination | 0,03 | 0,35 | 0,47 |
| Solid wastes | 0,28 | 0,55 | 0,32 |
| ENVIRONMENTAL | 0,43 | 0,62 | 0,60 |

**Table 13 Environmental indexes (first and second generation)**

### 4.2.2 Social dimension

The target defined in this dimension was 1. In Table 14 the results for the first and second generation indexes in social dimension are shown.

| INDEX | Moments of analysis | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Social capital | 0,04 | 0,48 | 0,78 |
| Well being | 0,17 | 0,17 | 0,30 |
| Legal commitment | 0,13 | 0,45 | 0,65 |
| SOCIAL | 0,11 | 0,37 | 0,57 |

**Table 14 Social indexes (first and second generation)**

### 4.2.3 Economic dimension

The economic target for each indicator also was defined as 1 according to the definition of each indicator. In Table 15, the first and second generation indexes of the economic dimension are presented.

| INDEX | Moments of analysis | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Economic performance | 0,00 | 0,01 | 0,06 |
| Satisfaction | 0,95 | 0,95 | 0,93 |
| Innovation | 0,00 | 0,11 | 0,13 |
| ECONOMIC | 0,14 | 0,17 | 0,20 |

**Table 15 Economic indexes (first and second generation)**

### 4.2.4 Sustainable Development Index (SDI)

In Figure 13, the results of the compilation of indexes of each dimension- environmental, social and economic- in a sustainable development index are shown.

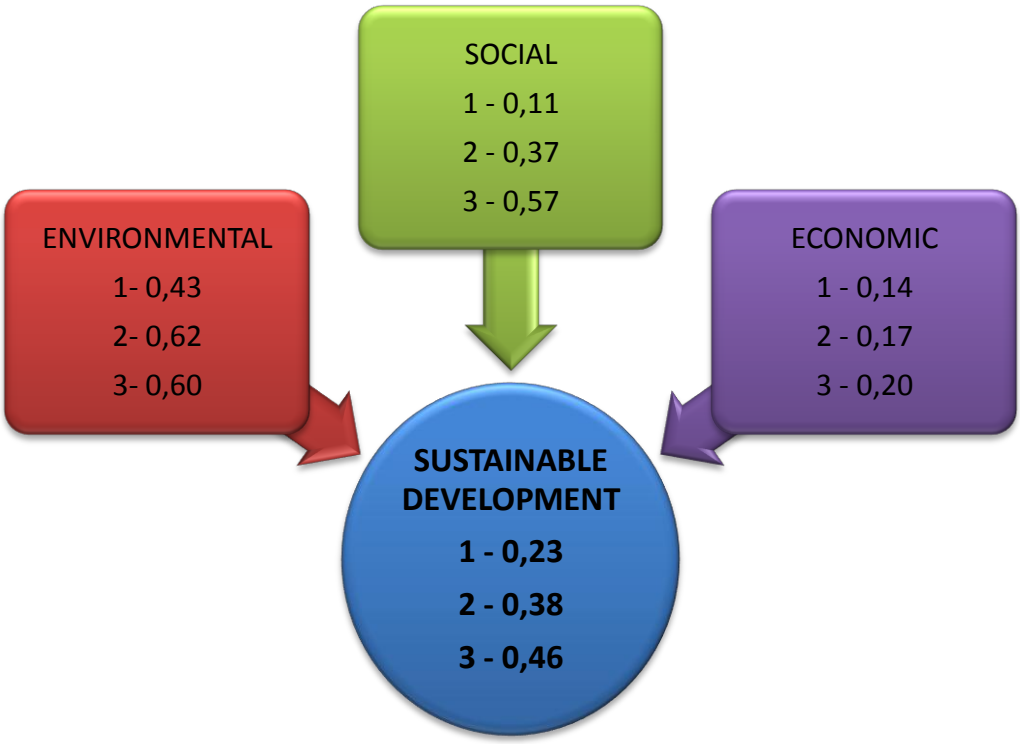



**Figure 13 Sustainable development indexes in different analysis moments**

## 5. Discussion

### 5.1 Cleaner production implementation

#### 5.1.1 Environmental diagnosis

Performance: According to the results presented in Table 4, the chemical inputs that present the main variation are lime and chromium. Lime is used in the region in excess since some tanneries use it for swelling the skin and to produce an extra amount of split leather, a by-product that is sold on a weight basis. Chromium presents high deviations due to the different recipes in tanning operations in the region. In addition, some tanneries use chromium in the re-tanning.

The average quantity of lime for the twelve tanneries (51.74 kg/ton) is higher than that reported by UNEP as the quantity of lime per ton of skin in the tanning process (45 kg/ton) (UNIDO en UNEP, 1994). Nevertheless, UNEP (1994) also presents a wide range of lime consumption between 20 and 100 kg/ton due to the variety of recipes for the tanning process around the world. In terms of chromium salt consumption, the average quantity is lower than that reported by UNEP (100 kg/ton). UNEP also mentioned a range of 5-6% of chromium for low chromium processes. The values of tanneries are lower than this range, only three of them present higher values than the average (60 kg/ton, 52.5 kg/ton and 65.6 kg/ton) (UNEP, 1994; IUE 2008; European Commission, 2009).

In terms of water, the International Union Environmental Commission (IUE) presented in 2008 a range of 12 to 37 $m^3$/ton of water consumption for a tanning process under good practices

conditions. The average value reported for the tanneries lies in this consumption range. In addition UNIDO mentions the common water quantity of 32 $m^3$/ton indicating wide ranges of consumption between different tanneries (Buljan *et al.,* 2000). The maximum value of the Villapinzon tanneries is lower than both references.

Tanneries that recycle water and make discontinuous washings have the lowest water consumption values. These industries send effluents through coarse solid filters and fat retention traps.

Differences among tanneries are reflected in high values of standard deviation and the wide ranges between maximum and minimum values. This is mainly due to the differences in recipes, type and size of the equipments, the particular productive process used at each factory, and the financial situation of each tanner.

*Pollution:* These indicators also present high deviations between the results with and without treatment as shown in Table 5. The minimum and maximum values show wide ranges of pollution parameters. These indicators correspond to the pollutant load per weight of skin, in which the quantity of discharged water is taken into account in the calculation, adding another variable that can increase the dispersion.

The higher pollutants are organic load, total suspended solids and chlorides. Organic load and solids come from the type of raw skin used, and chlorides are incorporated in the water stream as salt is added during the beamhouse operations. Most of the observed dispersion in chloride consumption is due to the use of pre-salted or fresh skins. In general, all values show a high standard deviation, in some cases surpassing the average value.

In spite of the dispersion, the values obtained are within the typical contamination ranges for tanneries under good practices conditions reported by IUE (IUE, 2008; European Commission, 2009). Those ranges are wide (BOD: 48-86 kg/ton; Cr: 3-7 kg/ton; TKN: 10-17 kg/ton; $Cl^-$: 145-220 kg/ton; $S^{-2}$: 2-9 kg/ton; TSS: 85-155 kg/ton) reflecting the variability in raw material and processes (IUE, 2008).

Among the tanneries with an end of pipe treatment, one of them presents very high contamination values. This is due to the fact that in the year 2008, year in which the samples were taken, the physicochemical treatment had not been well implemented, tested and improved in this tannery, these values correspond to the first samples taken of this system. Other tanneries had the system already installed and tested, indicating good results and complying with the current environment regulation. For some tanneries, the parameters that the system is not able to remove at this primary treatment are chlorides and nitrogen..

*Solid Wastes:* In terms of the solid wastes observed in Table 6, it is during the defleshing operation where the highest values are observed (289 kg/ton SD:113.33). UNEP reports a range for this residue of 70 to 230 kg/ton. This stage of the process is currently under investigation due to the fact that this residue may be used alone or mixed with other wastes to generate compost if it is separated from the process prior to the unhairing operation. For the recovered hair, the average value in the tanneries (129.5 kg/T, SD: 49.81) is higher than the maximum value of the range presented by UNIDO (100 – 120 kg/ton) about hair saving conditions (Fendrup, 2000). This result is satisfactory because it implies the correct form to apply the hair save technique, implemented as a cleaner technology, whose objective is to recover high quantities of hair.

In tanneries that process split leather, as is the case in two tanneries involved in this study, the beamhouse operations are not performed, so wastes from unhairing and defleshing are avoided. In general, the variations show the lack of standardization in the solid wastes management practices in the region. Nevertheless, prior to the interventions of the SWITCH project, tanners discharged

the wastes onto the soil or the river. Now they store them seeking value appreciation alternatives and awaiting the results of experiments that are being undertaken by the project's technical team with respect to compost from hair, defleshing wastes and trimmings.

### 5.1.2 Review of the literature and selection of BAT and GOP.

In the literature review, all the tanning process operations were taken into consideration. In the following stage the soaking, unhairing, deliming and tanning operations were selected, as these are the ones that generate the greatest contamination. These have represented a priority for the tanners and for this reason the availability of human, technical and financial resources has been possible. The technologies in the defleshing, pickling, retanning and dyeing operations were not selected by the tanners due to the difficulties that their implementation generate in terms of the above mentioned resources.

The defleshing technology prior to the unhairing operation implies new machinery and high costs for the tanners. Today, this alternative is feasible provided it is possible to integrate the leather production chain and to generate joint alternatives. Despite this, granting a value to this residue can motivate the tanners to work associatively and to have access to this technology in the future.

In the case of pickling without salt, new chemical inputs are needed and the costs of the operation increase. The tanners do not feel confident about its functioning and for this reason do not dare to make investments in this respect. Finally, in terms of the recirculation of dyeing baths, the current infrastructure does not allow the storage of the baths for another skin batch. The investments in CP have been destined to the recirculation of unhairing baths.

### 5.1.3 Follow up to BAT in the productive process

It is important to highlight that due to the specific characteristics of the micro-tanneries in the area and to the tanning activity itself, the results regarding the performance of the tanneries present a high variation. Since many industries lack monitoring systems, the parameters in only a few tanneries could be evaluated. Prior to analyzing the savings achieved in the tanning operations, it is important to establish the degree of informality and the instability in the production systems and the different recipes and products of these kinds of tanneries.

*Soaking:*

The pollutant load in the experiments presented reductions in BOD. These reductions are explained by the efficiency of the operations with the biodegradable agents. The conventional soaking usually did not use any surfactant, sometimes laundry detergent was used for soaking skins, increasing the organic load in the effluents.

*Unhairing:*

In this operation a lot of modifications have been included in these tanneries during the past five years. On the one hand, chemical suppliers have sold their recipes presenting different immunization agents and hair-saving products. On the other hand, tanners have reformulated their operations according to their experiences obtaining good quality products. In the end, a mixture of chemical supplier’s recipe and tanner’s recipe was implemented and some savings were achieved.

The tanners have also implemented a combination of recommended alternatives and their own form to reuse the water for the recycling baths. They do not have a technical control of this water.

In terms of sulphides, the total substitution of sulphide in the unhairing operation is not possible in practice, but the use of enzymes and auxiliary agents reduces sulphide consumption (European Commission, 2001).

The sodium sulphide present a reduction of 72 – 87% and the lime consumption presented a saving of 11% - 53% as shown in Table 8. A modified method for unhairing that includes recycling allows chemicals savings (lime, sulphide and unhairing agents) up to 28% (Nazer *et al.*, 2006).

In terms of the pollutant load, the reductions are presented for BOD (33 – 77%), TSS (79-98%) and $S^{-2}$ (72-87%). The savings for TSS and $S^{-2}$ load are higher than some values reported by UNIDO in terms of the hair saving techniques compared with the hair destroying techniques. BOD reported is within the range achieved in the experiments. Those reported reductions are in TSS (70%), in $S^{-2}$ (50 -60%) and in BOD (50%) (Fendrup, 2000).

According to Nazer *et. al.* when the baths are recycled four times the sulphide load is reduced at a range between 46% to 73% (Nazer, et al., 2006). UNIDO also reports reductions for the recycling of individual baths of unhairing. After 10 cycles of liming and 20 cycles of unhairing 70% of reduction in sulphide load is achieved (Ludvik, 2000).

Finally, according to the European Commission, sulphide load is reduced by 50% due to hair saving techniques and 50-70% with the recycling of unhairing baths (European Commission, 2001).

In adittion, an important result achieved in this stage of the process comparing the current situation with the situation in 2004 is the recovery of hair and the use of this by product as input of other process as composting generating utility for the tanners and avoiding the disposal of this waste in the soil without any management.

The higher values for the experiments can be explained by the combination of hair saving methods and recycling baths. In addition, it is of utmost importance to control the amount of water coming into the process and its output, and the recycling ratios for the operation. Nevertheless, the quality of those recycling streams must be strictly controlled to avoid a decrease in product quality.

*Deliming:*

This operation shows reductions of 27 – 99% in total nitrogen for the use of free nitrogen compounds. UNIDO reports a decrease for $NH_3$-N load of 97% in effluents discharged from ammonia-free deliming (Ludvik, 2000).

In the region, the improvements for this operation have not been implemented in many tanneries. All the efforts have been directed to the unhairing operation. Nevertheless, the changes have begun to show benefits and many tanners begin to believe that the improvements in this stage of the process also can be possible.

*Tanning:*

The experiments regarding the tanning operation show a saving of chromium amount at the entry of 1 – 33% and of 52 – 94% in chromium load (Table 8). According to existing references, the tanning operation implementing high exhaustion chromium presents reductions of 32% in chromium load (INTEC, 2000).

Another research study in the literature reports a decrease in the chromium offer required for the tanning operation from 15 kg/t to 10 kg/t corresponding to a 33% of reduction and a decrease in the chromium load of 97 – 98% (3.8 kg/t to 0.05 - 0.1 kg/t) (Ludvik, 2000).

The high exhaustion chromium operation in Villapinzón needs to be improved in terms of temperature management and control of process.

*Water consumption:*

In soaking, the saving of water is 19% comparing the results for 2009 and 2004 as observed in table 9. In unhairing, the water achieved reductions 42% (2009 to 2004). According to the literature, a modified method for unhairing that includes recycling allows water saving up to 58% (Nazer *et al.*, 2006). In deliming, the new recipes use low quantities of water presenting reductions of 17% comparing the results of 2004 and 2009 and the tanning operation presented the higher reduction of 68%.

In general, the reductions are achieved by adjusting the recipes and by controlling the water flow at entry in all operations of the process.

### 5.1.4 Follow-up and qualitative assessment

GOP and process alternatives show an intermediate degree of implementation in 2009 that improves in 2010 (Figure 12). These components of CP presented higher scores in 2010 than the wastewater treatment as assessment component of EOP. The latter can be understood as a gradual change towards prevention and adoption of preventive measures by the tanners.

The wastewater treatment as an end of pipe component presented one of the highest values in 2009. This score is explained by the fact that the regional authority pushes for the primary treatment as it has always been end-of-pipe oriented. In 2010, this component shows a slight improvement in the twelve tanneries but it is not the dominant value anymore. The tanners have been internalizing the CP concepts as their environmental solution and the preventive solutions are well adopted and innovative alternatives have been created by them.

The lowest values are presented by the solid wastes management. The latter is congruent with the reality; since they are only starting to work on those related issues. Some of them still continue storing wastes without any option for value appreciation, or disposal. Many others have found alternatives for their transformation and value appreciation.

Additionally, great efforts are being realized in this component from the tanners' association (ACURTIR) that on the one hand has obtained land plots for the collection and value appreciation of some wastes proper to the process; and on the other hand the SWITCH project supports research on the wastes to which it may be granted a value: hair, defleshing wastes, chromium shavings. Some difficulties arise derived from the dissociation that exists between land planning and environmental planning issues.

The tanner’s association (ACURTIR) purchased a land to gather the solid wastes and make solid waste valuation. The SWITCH project is sponsoring them on a solid valuation project where experiments are being carried out to implement in the region as valuation options like composting from hair and defleshing waste.

### 5.2 System monitoring structure

#### 5.2.1 Environmental dimension

In this dimension some goals were defined in terms of performance, pollution and solid wastes (Table 11), which according to the literature would reflect the optimal and real conditions of a tanning process, and would point at the sustainability of this industrial sector. These goals are still distant from the sustainable emission limits defined by the technical team IDEA (Santos *et al.,* 2010) in terms of organic load, total suspended solids, chlorides and chromium. In the sulphide load, the defined value in the goal is equivalent to the defined for the emission limit. These limits must to be reached in a long term.

According to the results shown in Table 12 there is a gradual increase in the improvement of the tanneries towards environmental sustainability comparing moments 2 and 3 with moment 1. At moment 1 no CP program had been implemented yet as a prevention strategy for contamination, but some tanneries had already started to incorporate changes in the process, and to build the primary waste water treatment system as a contamination control strategy. It is because of the above that the environmental index at moment 1 is 0.43, since in terms of environmental performance some type of solution had began to be implemented.

Between moment 2 and 3, a reduction can be observed from 0.02 (from 0.62 to 0.60). This is as a result of one of the tanneries under study (C2) for moment 2 tanned sheep skin contrary to the rest of the tanneries that tan bovine skin. In this case, the analysis carried out in terms of proximity to goals is different, especially in the case of solid wastes, due to the fact that the generation of these for this type of skin is minimal; in general the process is less pollutant. It is for this reason that the index of solid wastes for this tannery is significantly high (0.89) in comparison with the other industries, and even with their own values for moments 1 and 3. This value causes the environmental index for moment 2 to be greater than for moment 3. This change represents one of the dynamics of the region in terms of instability and lack of standardization in raw materials and final products.

Finally, the environmental index analyzed in the three moments reflect the behavior of the reality of the tanneries of Villapinzón in terms of environmental improvement, since this amount has been greater from moment 1 where the project is just starting maintaining the positive trend during moments 2 and 3, which correspond to the years of the implementation of contamination prevention alternatives.

*Performance:*

This index presents the highest value in each moment of analysis near 1 at moments 1 and 2, and 1 at moment 3. This indicates that the tanneries under study are within the established range for the designated goals for each indicator. Its performance in terms of the consumption of chemical inputs and water is optimal. Despite this, in the region's tanneries the practice of efficiently controlling the operations has not been interiorized; and the qualities of the inputs are reduced by economizing in costs in this regard, which diminishes the quality of the final product.

*Pollution:*

The goals of this index were established according to the environmental regulation of the region for industrial discharges onto the river. For moment 1 a very low value is observed (0.03), which is explained by the fact that the tanneries at this moment did not have a primary treatment system. At that time, they discharged the effluents with pollutant loads greater than the values established by the norm. This treatment system was built in the framework of the environmental management

plans carried out by the industries from the year 2005 with the support of CCB. During moments 2 and 3, this system has been increasingly improved, and for this reason, the quality of the water discharged into the river has improved. With respect to progress in this regard, it also has to do with the reduction of the pollutant load during the process, that is, the water that enters to the treatment system.

*Solid Wastes:*

This index increases between moment 1 and moments 2 and 3. Nevertheless, the behavior that moment 2 presents is not considered normal as one of the tanneries analyzed undertook the process of tanning sheep skin, a process that generates a minimum production of wastes, reason for which the proximity to the goal in this case is close to 1.00 (0.89). For the other tanneries at each moment, the maximum value reached is 0.53.

Among the solid wastes analyzed, the pre-defleshing waste is zero in all moments as this alternative is not carried out in the region. Nevertheless, it was included in the analysis because it has greater possibilities of industrial exploitation as it does not contain chemical products that change the properties of grease and fat (lipids, proteins, etc). In the case of the industry that tanned sheep skin, at moment 2 this indicator is 1 as this alternative is not feasible for this type of skin.

For the other wastes, both hair as well as defleshing wastes, shavings and trimmings it is necessary to continue with the technical advisory in its management, so that the production of these is standardized and corresponds to the optimal quantities that should be generated in productive tanning processes with CP.

### 5.2.2 Social dimension

Indexes presented in this dimension show an increase in the different moments of analysis, as can be observed in Table 14. It is proposed that the goal of this index is 1, that is, when its components attain their maximum levels.

For moment 1, the index gives 0.11 as a result, a figure that shows the social difficulties faced by the tanners during this period of time, made worse by the high level of legal, social and relationship conflicts inside the tanners' association as well as outside of it between the different business owners.

At moment 2 the index is 0.37, and at moment 3 it is 0.57, which demonstrates the advances obtained in the intervention and the accompaniment made with the tanners during the project, the implementation of activities of association building and the change of perceptions. The positive variation between moment 1 and 3 (six years) is 0.46, which shows the improvement in the level of social capital, well being and the reduction of legal conflict.

*Social Capital:*

For moment 1 this index has as a result 0.04, a value denoting the social crisis in which the sector found itself. This crisis presented high levels of tension in the existing relationships between actors, the lack of spaces of participation and no progress occurred in the improvement of production since they were not considered cleaner production alternatives, nor had good operation practices being implemented in the production process. In this moment, the indicators of access to participation and changes in the behavior were zero due to the little recognition the tanners had as important actors with respect to change and the lack of opportunities for participation in spaces that allowed them to have an influence on decision making.

At moments 1 and 2 this index gives as results 0.48 and 0.78 respectively. With this variation the high positive impact of the intervention is shown realized through the participative-action-research that has been implemented in each one of the components on the part of the SWITCH-IDEA technical team. In these moments of analysis an improvement is evident in the change of the relationships and in the access to participation settings, obeying changes in social imaginaries of the sector, where the tanners of Villapinzón and Chocontá are currently recognized as change actors and drivers of the improvement in the implementation of CP and GOP, which for the first moment were null, since the intervention in this regard had not been initiated.

The changes in social capital, positively impact all levels and components of analysis since it is on the basis of the evidence of improvement in relationships that substantial changes can be generated in the social dynamics.

*Wellbeing:*

For moments 1 and 2 this index provides 0.17 as the result, taking into account that its components (gender equality, level of education, and social security) did not undergo modifications from one moment to another. For moment 3, this index increases to 0.3 due to the increase in the level of education of the tanners generated by generational changes and the hiring of women in administrative levels, changes generated by the daughters of the tanners who now occupy administrative positions and with decision making power.

Nevertheless, no substantial changes are observed due to the fact that the coverage in social security is null, since the sector counts with subsidized health coverage, which is reflected in the low level of affiliation to health care and pension on the part of employers and the lack of interest on the part of workers to become part of the contributory health care system.

*Legal Commitment*

At moment 1, this index is 0.13, a value that represents the acute level of conflict, the penalty fines to the tanners and the incompliance with the environmental regulations originated by the inefficiency of the productive processes and the lack of knowledge of the legal requirements. In this moment, all the tanners had open legal processes, suits and fines.

For moment 2, although the fines continued, the index increased to 0.45 given the level of compliance on the part of the tanners with the environmental regulations. Finally, for moment 3, it increases to 0.65 due to the fact that the legal processes had being closed and the accompaniment for the legalization of environmental permits has been apparent manifest.

The change between the moments of analysis has been evident. The sector has improved thanks to the accompaniment in legal, environmental management, and business processes and to the increase of commitment on the part of the tanners. The social imaginaries have changed with respect to the sustainable industrial behavior.

### 5.2.3 Economic dimension

The economic index presents a slight but gradual increase, as can be observed in Table 15. The tannery sector has shown improvements in terms of productivity and competitiveness approaching the development of new products, the creation and diversification of a portfolio and the improvement of the quality of the final product. Nevertheless, the index at moment 3 (0.20) is low with respect to the established goal (1), which indicates that the tanners have still not reached the levels of quality and performance required by the market.

*Industrial Performance:*

This index highlights the incidence of the unit variable costs (raw material, labor, contracted services, indirect manufacturing costs) in the final price structure, which influences the level of competitiveness per type of product.

At moment 1, the value of this index is 0 as the participation of unit variable costs per decimeter over the final price, for products like lining and tula reach 93% and 97% respectively, denoting a robust cost structure derived from a high use of chemicals, the low capacity of negotiation of the skins and the low yield in the areas of finished product (decimeters). These low levels of innovation, productivity and the precarious financing capacity limit the growth of the industries.

For moment 2 the index reached a slight increase to 0.01 explained in the contribution margin reached by two new products (Tailoring nappa and split leather), with a lesser participation of unit variable costs per decimeter on the final price (61% less than at moment 1). At this moment, there are still low levels of innovation; nevertheless two of the tanneries had developed new products offering a greater financing capacity with a growth projection.

At moment 3, the index increases to 0.06, underlining a greater level of productive efficiency explained by the development of new products on the part of five tanneries of diverse types of nappa for shoes and leather goods generating greater contribution margins with respect to tula leather and lining.

*Satisfaction*

The analysis of this index is carried out calculating the percentage of buyers that have not reported complaints due to the quality of the production batch of the tannery that is commercialized.

At moments 1 and 2 nearly 95% of the buyers were satisfied with 82% of the production of the tanneries that was commercialized. 6% of the buyers reported complaints with respect to quality.

Comparatively, at moment 3 the index presented a reduction of 0.02, explained by the increase of the sample with tanneries with incipient production improvement processes. The latter increased the defective batches so that only 77% of the batches were commercialized and the increase in the percentage of buyers who reported complaints grew to 9%.

The high satisfaction percentages, in relationship with the low level of industrial performance indicate that the products have appeal in a segment that demands shoes and leather goods of medium quality at low prices. Likewise, the tanneries do not carry out follow-up to their clients' satisfaction, reason for which they do not have reliable information to back this information.

*Innovation*

This index was analyzed, comparing the participation of new products in the portfolio with respect to the total number of products per season; and the participation of the tanneries that accomplished new developments in the products.

The innovation of products in the sector at moment 1 was 0. For this moment only tula leather and lining were produced, and there was no type of innovation present. At moment 2 the index increased to 0.11, as two tanneries developed two new products (tailoring nappa and split leather)

At moment 3, the index increased to 0.13 with innovative products with respect to the tannery sector with four new products (grained nappa, floater leather, vegetable tanned nappa, waterproof

nappa) and new trends in tailoring nappa. The developments were carried out by five tanneries that on the basis of the technical workshops in development and accompaniment in entrepreneurial integration, achieved the diversification of the portfolio of the tanners' association (ACURTIR).

### 5.2.4 Sustainable development index

The results that this index sheds, shown in Figure 13 reflect the process of improvement that has been undertaken at the tanneries of Villapinzón and Chocontá during the past 6 years.

The first moment in all the dimensions obtained the lowest values in the indicators, and indexes since it is at this moment when the environmental, social and economic situation of the sector was experiencing its deepest crisis. During the conflict resolution process carried out as a doctoral dissertation of UNESCO IHE and the CP research made by the IDEA of the Universidad Nacional of Colombia, a comprehensive and preventive strategy was able to be established jointly with the tanners.

The most significant progress is observed from moment 1 to 2, the period in which the cleaner production process is initiated and the consultations in terms of cost structures, product innovation and improvements in the social capital. During moments 2 and 3, there is a positive change taking place, although not as high as the one from the previous period, which reflects the period of follow up subsequent to the implementation.

The indexes of each dimension and the index of sustainable development show gradual progress in the sector, of an environmental, social and economic type at moments 2 and 3. It is also observed that if indeed there is an increase the ideal state has not been achieved where the indexes would have values of 1. For this reason it is necessary to grant continuity to the processes of improvement in the environmental aspects through contamination prevention measures, the increase of the social capital, wellbeing and a dynamization of the tanning economy.

**Conclusions**

Among the most relevant results of the CP implementation process is the contribution and active participation by the tanners in the innovation and development of cleaner alternatives for their production process. Especially in the unhairing operation, the experience of the tanners has been combined with the technical knowledge of processes from experts in the tanning process achieving reductions between 2004 and 2009 in the pollutant load (BOD: 33 – 77%; Sulphides: 72 – 87%) at the water source and improvements in the performance of the industries represented in reductions of water and sodium sulphide consumptions (Water: 42%; Sodium sulphide: 10-57%).

Through the follow up and assessment made to the CP implementation, the component that has caused the major impact in this research has been the GOP presenting an advance between 2009 and 2010. This progress is represented in the scores of the assessment (2009: 2.0; 2010: 2.5). The tanners are gradually improving from the most economic and feasible changes to more elaborated and technology-driven adaptations.

The trend in the long term has shown that the tanners are successfully adopting behavioral changes towards prevention as it is shown in the follow up and assessment comparing the score of the alternatives inside the process (2009: 1.9; 2010: 2.3) and the waste water treatment (2009: 2.0; 2010: 2.2). These behavioral changes have proven to lead to creative outcomes and innovation.

The progress that the index of sustainable development shows in the three moments of analysis (1: 0.23; 2: 0.38, 3: 0.46) is an evidence that the environmental conflict of years back has generated an interest in advancing towards the sustainable development of a stronger, organized and cleaner sector. The participation of the whole sector has made their own the process of transformation from the environmental, social and economic spheres. This gradual increase indicates that the comprehensive efforts towards the improvement in all dimensions must be continuously reinforced.

**Recommendations**

It is important to establish economic incentives for environmental improvements so that the change process can be assured and the cleaner production is thus viewed by the tanners as a cost-benefit process.

With the aim of making the tanning activity a sustainable one, it is necessary to grant continuity to the improvements in all dimensions. The work on cleaner production and in the prevention of contamination must be continued as well as the work in strengthening the social capital, access to spaces of participation, the collective participation in the generation of new strategies, the dynamization of the market, increasing the quality of the products and accessing new markets.

In order to implement CP over the long term, all the efforts mentioned above can be useless if there isn't an appropriate institutional framework to back it, and if land and environmental issues do not complement each other.

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