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SWITCH Document: **Sustainable industrial emission limits for 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 To contribute towards the development of sustainable leather tanning, through the quantitative definition of the maximum discharge limits from tannery effluents. The specific objectives of the research was 1. To develop sustainable emission limits for the tanning industry. 2. To define the gap between the emissions of a conventional tanning industry, the defined sustainable emission limits and the emission reduction options for the process. 3. To describe the long-term consequences of applying sustainable emission limits.
Background The tanning industry is highly polluting. The traditional tanning process requires large amounts of water (40 m^3 of water/raw hide; European Comission, 2009). Wastewater is a major problem due to its volume and high organic load from dehairing and tanning operations (BOD 14000 mg/L)(CCB, 2005). Solid waste volume is high where 62% of the initial skin becomes solid waste and are deposited in a sanitary landfill or in the soil without any type of treatment. Emissions from tanneries are discharged onto natural systems that have the capacity to assimilate a certain load of contaminants occurring as a result of natural processes to which it is subject to, such as the decomposition cycle of organic matter, as well as nitrogen, phosphorus, and sulfur cycles, among others. If these levels are surpassed, as for example in the case of the cycle of organic matter, dissolved oxygen is lost reaching 0 mg/l in the river. In the river the consequences are the generation of foul odors and the annihilation of some species (Chapra, 1997). Therefore, the emissions that contaminant effluents deposit in a system should be defined in accordance with the specific capacity that the ecosystem has in assimilating the pollution. There are discharges containing heavy metals, toxic substances, and pesticides that an ecosystem cannot assimilate because no existing natural cycles can transform them. These contaminants accumulate in sediment, plants or in animals.

The document analyzes tannery emissions, and according to their impact and the capacity of the system to assimilate the contamination, maximum emission limits are defined, keeping in mind the long term effects on society and the economy.

Limits are established taking into consideration the best existing technologies and techniques available to improve the environmental performance of these industries. Existing techniques depend on the commitment on the part of business owners, and requires continuous training and education in order to achieve sustainable emission limits.

Finally, a short, medium and long term strategy is presented in order to achieve the emission limits, jointly developed with the tanners of Villapinzón and Chocontá and in accordance with their economic capacity and the regional situation. This strategy may be replicated in other regions that have groups of tanneries with similar characteristics.
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Potential Impact

Sustainable emission limits are defined in terms of contaminant load for the liquid effluents in order to seek the least consumption and discharge of water and in consequence the least contamination. In addition, with respect to those compounds the environment is not able to assimilate, it is proposed that these not be discharged so that they do not accumulate. Over the long term the impact is the reduction of contamination by heavy metals, and chlorides in the sediment, animals and plants.

Water in the Bogotá River will improve its quality by reducing the contamination stemming from the tanneries. As this River is used to supply drinking water to the capital city, the costs associated with water treatment for human consumption will decrease.

It is proposed that over the long term solid residues not be discharged onto the environment, as these may be reused, or recycled in other production processes. In this manner contamination in the river and in the region's soil will diminish. If solid residues are exploited collectively by the tanners, they will have a new source of income and will not have to invest in depositing solid residues in the sanitary landfill.

Emission limits with a focus on sustainability and keeping in mind the long term effect may be applied in other regions of the country and the world.

Recommendations

- Sustainable emission limits should be set for the tanners as an environmental improvement goal for the industries thus reflecting their commitment. Its implementation should be undertaken by stages, accompanied by the constant education and training of the operators. Achieving the limits does not solely depend on the application of new technologies, but in the behavior of the operators and tanners and in establishing best practices in the process.
- The environmental authority should formulate regulations that concord with the work being advanced by the industries so that cleaner production is promoted as a way to reduce contamination.
- To reach the limits, collective work is required from the tanners, in such a way that they may organize themselves in order to undertake the secondary treatment and the valuation of the solid residues. Economically it is not sustainable for each tanner to have the required infrastructure.
- A commitment from all stakeholders is required in order to support this initiative, and to achieve the final objective in the region, which is to improve the water quality of the Bogotá River.

D4.2.1: A report listing 'sustainable industrial emission limits' as well as the motivation for each of the presented limits. The report describes qualitatively the long-term consequences of the application of sustainable industrial emission limits for society and the economy.
The release of this report is the starting point for determining the extent to which industries have to cut back the emission of certain components.

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1. Introduction.

Traditionally the tannery industries have been characterized as being highly polluting, requiring huge quantities of water with discharges of organic matter, nutrients, heavy metals (Chromium), Chlorides and Sulfides.

Some of these contaminants, may be assimilated by the environment as these belong to natural cycles (such as organic matter, nutrients, sulfides, carbon). Nevertheless, other chemicals used in the production process do not naturally degrade and accumulate in diverse ways such as in sediment, or are absorbed by some plants, in such a way that they remain in the environment (Chapra, 1997).

The sustainable emission limits of the tanneries must be defined according to the capacity that the receiving environment has in assimilating the pollution and the long term consequences of the discharges, keeping in mind its possible storage in sediments, animals, or plants that are exposed to the pollution.

In this report, an analysis is presented of the inputs into the conventional leather production process, the emissions of the process, and the non-sustainable flows, that is, flows that the environment can not degrade. This results in a proposal of maximum allowable tannery emission values, and an economic and social analysis of the adoption of these limits.

Emission limits for the tannery industry have been previously established in different international norms. The difference with the focus provided in this document lies in that the adoption of limits is proposed from the perspective of long term sustainability, where it is expected that discharges of contaminants that the environment cannot assimilate will not be carried out.

In order to be able to establish limits, a strategy is proposed stemming from the awareness raising of the tanners and the training of the operators to implement improvements to the production process.

The long term benefits of reaching these emission limits for the region are the reduction of pollution and as a result the reduction of the existing conflict regarding water usage. The water of the Bogota River in the upper basin may be able to be used without risk for the population that currently uses this water for irrigation and for human consumption.

For human consumption in particular, the water treatment costs will decrease, by drinking better quality water from the source, the result of the reduction of contaminant emissions from the tanneries. In this upper basin is located one of the potable water treatment plants that supplies 30% of water to the population of Bogota, capital city of Colombia. Although it cannot be affirmed that the plant's treatment costs are due to pollution from the tanneries, costs will decrease by reducing the contamination generated by the tanneries.

1.1. Goal of the research.

To contribute towards the development of sustainable leather tanning, through the quantitative definition of the maximum discharge limits from tannery effluents.

1.2. Objectives of the research.

1. To develop sustainable emission limits for the tanning industry.

2. To define the gap between the emissions of a conventional tanning industry, the defined sustainable emission limits and the emission reduction options for the process.
3. To describe the long-term consequences of applying sustainable emission limits.

2. Background.

2.1. Sustainable emissions limits.

2.1.1. Sustainability.

The sustainable development concept is based upon the sustainability of human activities aimed to supply basic and complementary needs, as explained by Brundtland (1987) in the report Our Common Future: "Sustainable development is the development that satisfies present needs without compromising the ability of future generations to satisfy their own needs".

As a natural system, a river has the capacity to assimilate a certain load of contaminants occurring as a result of natural processes to which it is subject to, such as the decomposition cycle of organic matter, as well as nitrogen, phosphorus, and sulfur cycles, among others.

If these levels are surpassed, as for example in the case of the cycle of organic matter, dissolved oxygen is lost reaching 0 mg/l in the river. In the river the consequences are the generation of foul odors and the annihilation of some species (Chapra, 1997). Therefore, the emissions that contaminant effluents deposit in a system should be defined in accordance with the specific capacity that the ecosystem has in assimilating the pollution.

There are discharges containing heavy metals, toxic substances, and pesticides that an ecosystem cannot assimilate because no existing natural cycles can transform them (Chapra, 1997). These contaminants accumulate in sediment, plants or in animals.

In economic terms, it is costly for society to use water containing traces of heavy metals for human consumption or irrigation due to the treatment cost in itself, and the possible effects of bioaccumulation. It is more effective to control the source of the discharge of these types of contaminants.

The adoption of emission limits should be undertaken gradually and according to the specific regional development characteristics, in such a way that the long term sustainability of the system is sought after, seeking the benefit of the communities and of the environment they inhabit. If emission limits are established immediately and without a staged process, they will not be sustainable due to the costs implied, and the changes in terms of habits of the social groups that should adopt them.

2.2. Tanning process description and emissions.

The tanning process transforms the skins of cattle (bovines), sheep (ovines) and pigs (sudinae) into leather. It consists of removing the hair, the non structural elements and fat off the skin to obtain pure collagen material. The durability, resistance and immunity to biological deterioration is obtained by impregnation with tanning agents (Colciencias, 2004).

The first stage is the pretreatment and storage (Table 1). To store the hide, salt is applied over the fleshy side in order to preserve it over long periods of time and to avoid its rotting.

The second stage of the process is known as beamhouse and is composed of sub-processes that ensure the allowance of adequate degrees of humidity and ready the skin for tanning. Initially a deep wash is performed on the skin to remove salt, manure and any dirt body (soaking); subsequently lime (liming) and sodium sulfate are applied to open the collagen structures and dissolve the hair (fur), facilitating the removal of unwanted material. Then comes the process of flesh removal (fleshing) which consists of retreating the excess inner tissue from the skin, followed by dehairing by means of an application of different chemical substances and a washing is done and the lime removed to condition the skin and allow the entry of the tanning agents.

The final stage of the process is known as tanning, where tanning agents are applied. Typically chromium salts that make it possible to provide the skin with its resistant properties. Depending on the desired product, different finishing processes are applied, where the tanning process is repeated, specific tinctures are applied and oils are added that allow a recovery of its shine and flexibility (ACERCAR, 2001).

Table 1. Tanning Process stages, inputs and outputs.

Stage	Process	Description	Inputs	Outputs Solids (s), liquids (l), gas (g)
Storage	Salting	Salt additon for preserving purposes	Salt	Salt (s)
Beamhouse	Soaking	Hide rehydration	Enzymes, Calcium carbonate Water Moisturizers, bactericides, detergents, desinfectants	Defleshing fat (s), Organic matter(l), surfactants(l), Chlorides (l).
	Dehairing and Liming	Epidermis swelling, dehairing, fiber stiffening to made tanning easier.	Sodium sulfide Lime Enzymes Sodium Hydrosulfite	Hydrogen Sulfide (g) Fat, Hair (s) Organic Matter, S, pH > 11, Oils and Fat (l)
	Defleshing	Fatty tissue, subcutaneous, muscle and fat remotion.		Fat (s) Dissolved proteins (l)
	Cutting	Splitting carnaza from flower		
Tanning	Deliming	Lime and sodium sulfide residues remotion	Formic acid Sulfuric acid Ammonium sulfate Sodium bisulfite	Hydrogen Sulfide (g) Lime (l) Sodium Sulfate (l), Nitrogen Organic (l)
	Purge	Impurities elimination with enzymes.	Enzymes	Organic Matter (l)
	Pickling	Hide acidifying for preventing swelling and to let chromium salts fixing	Formic acid Sulfuric acid	Chlorides, low pH (l)

	Degreasing		Salt Solvents	Solvents (g) Oils and Fat (l), Organic Matter (l)
	Tanning	Giving hide structural strength rotting resistance	Chromium sulfate	Hydrogen Sulfide (g) Cr^{3+} (l)
	Alkalinization	Adding salts to increase pH and to make easier the chromium 3+ reaction	Sodium bicarbonate Magnesium oxide Sodium carbonate	Sodium carbonate (l) organic acids (l)
	Dewatering	Expelling and pressing to eliminate moisture		
	Splitting	Cutting to obtain desired thickness		Chromium dust (s)
Retanning Dyeing Greasing	Cationic Retanning	Acidifying, Adding chromium salts to increas elasticity and softness.	Chromium sulfate Organic acids	Organic Matter (l)
	Dyeing	Giving a required color to leather.	Coloring agents	Ammonia (g) Dyes, Acid, ammonia, (l)
	Greasing	Saturating leather with animal fat	Animal oil	Oils and Fat (l), Organic Matter (l)

2.3. Environmental/ecotoxicological consequences of the emissions.

Emissions from the tanning process are: solid, liquid and gaseous. They can be described as dangerous or non dangerous. Classifying them as reusable, recyclable or disposable depends on the legal context of each country, but also on the available markets and facilities for treatment and recycling (European Commission, 2003).

The traditional tanning process requires large amounts of water (40 m^3 of water/raw hide; European Comission, 2009). Waste water is a major problem due to its volume and high organic load from dehairing and tanning operations (BOD 14000 mg/L)(CCB, 2005). Solid waste volume is high where 62% of the initial skin becomes solid waste. In some tanneries solid residues are recycled as hair composting and fat valuation, or they are deposited in a sanitary landfill or in the soil without any type of treatment.

When tanning waste water is discharged directly onto a water body it causes negative effects on aquatic life and the subsequent uses of these waters. The specific components that cause problems to the water bodies are chromium, sulfates and the organic load (CONAMA, 1999).

The effects of tanneries' emissions on environmental quality and on human health is described below, emphasizing those from dumping, as these are a significant problem in this production process.

The river has the capacity to assimilated organic load according to the cycles of the elements in the biosphere, such as carbon, nitrogen, phosphorus, sulfur. This phenomenon is known as self-purification of the river. The effects that contamination by organic matter produces in the river are esthetic, foul odors, the death of superior aquatic life, the transmission of diseases due to the high concentration of bacteria linked to the organic matter, such as coliforms, *E coli.* Inorganic nutrients, when they are found in excess amounts in the hydric source produce the phenomenon of eutrophication that is excessive plant growth. Sulfides take part in the decomposition process of organic matter (Chapra, 1997).

Other contaminants like heavy metals, cannot be assimilated by the environment so that these accumulate in the ecosystems in sediments, plants or animals according to the mobility characteristics in the environment. This type of contaminants can produce an effect on the health of whole communities if the water resource downstream from untreated discharges is consumed. Chlorides are long standing in water and its concentration is only reduced by longitudinal dispersion and dilution processes (Santos, 2010).

a. Organic matter COD and BOD.

Chemical or Biological Oxygen Demand (COD or BOD) are pollution parameters for the amount of organic compounds in a water body and the degradation speed of effluents. The presence of high COD and BOD concentrations in water bodies generates a deoxygenating action in them, which cause foul odors and death to aquatic fauna (COTANCE, 2002). The largest increase in organic load occurs in the beamhouse phase, during soaking. Organic substances dumped as effluents are biodegradable, but they increase the BOD, which depending on the assimilation ability of the receiving water body, could annihilate entire species. (Bosnic *et al.*, 2000; European Commission, 2003).

b. Nitrogen.

Nitrogen has an important influence on dissolved oxygen and is therefore relevant for water quality. Nitrogen is converted from inorganic to organic by plants and microorganisms present in water; it occurs in four forms: organic nitrogen, ammonia nitrogen, nitrate and nitrite. Several components of effluents from tanneries contain it. The most frequent are ammonia (derived from the deliming and dyeing processes) and nitrogen contained in proteinaceous material (derived from the deliming process). These nitrogen sources have two big problems:

1. Plants require nitrogen in order to grow. When there is a high level of nitrogen in the water, a rapid and excessive growth is generated, which impedes the flow of currents and generates a high demand for oxygen. When plants die, a great quantity of organic matter that cannot be decomposed (due to the absence of bacteria) is created and this facilitates the development of anaerobic conditions.

2. Nitrogen liberated from deliming in the form of ammonia is transformed by the bacteria in gaseous nitrogen and is released into the atmosphere; large quantities of oxygen are required for this process, which can rapidly create anaerobic conditions (Bosnic *et al.*, 2000).

Ammonia (NH_3) results from the decomposition of organic nitrogen or from inorganic matter. In the tanning process this compound is derived from the dehairing and liming processes Ammonium nitrogen exists in two forms in water: NH_4^+ (ionized) and NH_3. The organic and inorganic nitrogen oxidizes in the nitrification process that proceeds along two stages forming nitrite (NO_2^-) and finally nitrate (NO_3^{-}). To achieve this process requires oxygen which significantly decreases its levels in the water body. In concentrations of 0.01 - 0.1 mg/L, NH_3 is toxic to fish. The concentration of this compound depends on factors like temperature and the pH . The exposure to ammonia by water ingestion is estimated in 0.36 mg/day for a person drinking 2 L/day.(Bosnic *et al.*, 2000; European Commission, 2003).

The presence of high nitrate levels in drinking water can lead to metahemoglobinemia, a pathology that primarily affects infants under six months of age. Concentrations in excess of 10 mg/L can cause the disease (OMS, 2003). In animal studies (mice, dogs, pigs, rabbits), ingestion of ammonium chloride from 500 to 1,000 mg/Kg/day during 1 to 8 days causes metallic acidosis. However, there are no threshold values for humans due to the absence of studies evaluating oral exposure (ATSDR, 2005).

c. Sulfides (S^{2-}).

Sodium Sulfide and Sodium Hydrosulfide are known for causing various environmental problems. Under alkaline conditions sulfides stay dissolved, but when the pH descends below 9.5, hydrogen sulfide is produced by the presence of acids in the effluents. As the pH decreases, there is an increase on its rate of production. This generates foul odors and increases the risk of inhalation of these toxic vapors. Even in low concentrations sulfides have a toxic potential if they are discharged in surface waters. This situation is preventable by performing a neutralization of acid effluents before being discharged to the general effluents (EPA, 2003).

In aired waters some bacteria can oxidize the sulfides into non toxic compounds, but at the cost of a great demand for oxygen, which puts aquatic life in jeopardy.

Sulfides have diverse effects on human health depending on the exposure mode. By inhalation, it causes acute damage to the mucous respiratory membranes, which become apparent with cough and dyspnea, and can result in pulmonary edema. On contact with the skin and the eyes, it causes burns and risk of blindness due to damage to the cornea. Its ingestion causes burns on the mouth and in the intestinal tract with vomit, gastrointestinal hemorrhage, and perforation of viscerae. At the systemic level it causes disorders to the Central Nervous System. No data exists with regard to chronic toxicity from hydrogen sulfide in humans (WHO, 1988). Different effects can be observed in the health of workers (dermal lesions, respiratory tract affectations, burns, etc) by direct exposure to chemicals during the tanning process.

d. Fat and Oils.

During the manufacture of leather, an important quantity of natural oils and fat are released from the skin. Floating fat and fat particles that build up, bind to other materials causing blockages in the treatment plants. In surface waters that become polluted with fat or layers of oil, the oxygen transference with the atmosphere is reduced. If these fat particles emulsify, they generate a large increase in oxygen consumption (Bosnic *et al.*, 2000; COTANCE, 2002).

e. pH and Temperature.

Limits to the pH value from residual waters discharges into surface and drainage waters can vary in a range of 5.5 to 10.0. Although strict limits have been established, there is a degree of tolerance towards elevated pH values due to the fact that atmospheric CO_2, or CO_2 formed in biological processes that occur in surface water, diminishes the pH. Some species are susceptible to variations of the pH. Wastewater treatment plants prefer alkaline water because it reduces the corrosive effects on concrete, lets metals remain insoluble (thus inert), and reduces the production of Hydrogen Sulfide (Bosnic *et al.*, 2000).

The rise of temperature in water reduces the solubility of present gases (oxygen and nitrogen) due to chemical reactions such as evaporation and volatilization. Also, warm water influences the increase of the respiration rate of aquatic organisms producing high oxygen consumption (Porras, 2004). This is relevant for discharges of effluents from tanneries that use hot water in particular phases of the process.

f. Chromium (Cr).

The most frequently used tanning agent is Chromium (Cr). Decades ago, the source was Hexavalent Chromium (Cr^{6+}), which by oxidation delivered trivalent chromium (Cr^{3+}) to be used in the production process (Díaz, 2008). Cr^{+3} is a heavy metal with a poor capacity to dissolve and an easy sedimentation that does not pose any serious health problem, in comparison with Cr^{+6} that is easily soluble in water and depending on the manner of exposure it has the potential of producing dermal, renal, pulmonary and gastrointestinal alterations. For this reason, chemical suppliers do not sell products which include Hexavalent Chromium. Chromium salts that do not attach to the collagen are discharged into the effluents to the environment, especially water and soil (Ludvik, 2000; ATSDR, 2005).

Industrial waste water is the principal source of Chromium in surface waters. The most important mechanisms for the removal of Cr^{+3} from the aquatic environment are precipitation as $Cr_2O_3 * H_2O$ with subsequent sedimentation. Hexavalent Chromium is a moderate oxidizing agent and can react with organic matter and other reduction agents to form Cr^{+3}. In this way, in surface waters rich in organic matter, Cr^{+6} can have a short half life (EPA, 1998; ATSDR, 2005).

Effects in animals: Measures of the effects of trivalent chromium in water show that due to its low solubility (experimental conditions of pH=7), Cr^{+3} does not produce toxic effects in bacteria, marine algae or fish. Only the Daphnia shows a marked sensibility to concentrations in the order of 6 to 9 mg/L (ATSDR, 2005).

Toxicity of Chromium compounds in animals depends on the valence, as well as on the specific physiochemical properties of the compounds. In general, acute toxicity of Chromium compounds in animal experiments increases with the solubility in water. The LD_{50}[1] for trivalent compounds has been reported in ranges of 140-522 mg/Kg and the LD_{50} for hexavalent compounds is in the range of 13-795 mg of Cr+6/kg (Canadian Environmental Protection Act, 1994).

Effects in soil: Although Chromium is naturally present in its inert form Cr^{+3} in many soils, with time it can be mobilized by way of acidic lixiviation (podzolization). Cr^{+3} can be oxidized to Cr^{+6} by manganese oxides present in the soil, but only a small percentage of Cr^{+3} in the soil normally presents oxidizing forms. Cr^{+3} oxidation to Cr^{+6} is facilitated by the presence of mixes and small quantities of organic matter, and can be increased on the surface of the soil by elevated temperatures created by fires (Canadian Environmental Protection Act, 1994).

The main toxic effects on soil microorganisms are a decrease in their growth and number. In vegetables various studies have been undertaken in which it is concluded that trivalent Chromium compounds can be considered non-toxic in concentrations smaller than 500 mg/kg. A precaution is

[1] In toxicology, the median lethal dose, LD_{50} (abbreviation for "Lethal Dose, 50%"), of a toxic substance or radiation is the dose required to kill half the members of a tested population after a specified test duration. (IMDG, 2006,)

noted, however, regarding the Chromium $^{+3}$ property of accumulating in the soil, altering its biota (ATSDR, 2005).

Human health effects: Trivalent Chromium has a fundamental role in the metabolism of glucose in humans and animals (Canadian Environmental Protection Act, 1994). This means that the Cr^3 is necessary for humans.

Hexavalent Chromium presents an important genotoxic potential reported in various studies, although the results are limited by the presence of co-expositions to other potentially genotoxic agents (ATSDR, 2005; Junior *et al.,* 2006).

g. Sulfates (SO_4^{2-}).

These are compounds derived from the use of Sulfuric Acid and products with a high Sulfate (Sodium) content. Because these cannot be removed completely from the solutions by chemical, certain biological conditions are used to remove the sulfates and to bind them to certain microorganisms. Nevertheless, a remnant of Sulfate persists that is decomposed by anaerobic bacteria creating Hydrogen Sulfide (Bosnic *et al*., 2000; EPA, 2003). Effects of Sulfates on human health are given by its temporary laxative effect at high doses. Infants, the elderly or handicapped are sensitive to high doses of Sulfates in drinking water (greater than 500 mg/L) (EPA, 2003).

h. Chlorides (Cl^-).

These are generated in effluents by the use of great quantities of Sodium Chloride in the preservation of the raw material and in the process of pickling. The beamhouse stage alone accounts for more than 40% of the total load of dissolved solids generated during the manufacture of leather. In traditional methods, the concentrations of Sodium Chloride in effluents can reach 22,800 mg/l (Padma *et al.,* 2006). The importance attributed to the total load of salt released depends on the specific environment at the discharge site, just as with the type of residual treatment plant or the type of surface water bodies within which the tanneries or the treatment plants make their discharges (Bosnic *et al*., 2000; COTANCE, 2002).

Chlorides inhibit the growth of plants, bacteria and fish in surface water bodies. At high levels it can cause damages to the cellular structures. If the water is then used for irrigation purposes, the surface salinity increases with evaporation and causes damage to plant leaves. When it precipitates to the ground due to rain, chlorides end up once again in groundwater. High salt contents are only acceptable if the effluents are discharged into marine environments (Ministerio de Medio Ambiente España, 2003).

Constant irrigation with an effluent rich in Sodium Chloride harms vegetation due to the Chloride ion being phytotoxic. On the other hand, the sodium ion is also harmful as it damages the soil structure disintegrating the clay and affecting the porosity of the soil (COTANCE, 2002; Padma *et al*., 2006).

2.4. Financial and social aspects of applying sustainable emission limits.

The social and financial aspects for the application of sustainable emission limits should be analyzed from two perspectives: at the level of effects on the basin (regional) and at the industrial level (local). The first level is linked to the economic and social implications for communities located in the basin downstream from the effluents. For example, if the water is used for irrigation or human consumption, the cost implied in terms of the health of the inhabitants who consume the water or that use it for irrigation without treatment, or the cost of treatment to enable the water to be used.

The second level relates to the economic and technical capacity of the industries to undertake productive process improvements in order to reduce the contamination and the construction and operation of the final treatment in order to reduce the concentration or load in the effluent discharge.

In the study region there are established discharge limits for tanneries in terms of concentration of physicochemical parameters. The limits are based on water quality goals in the river fixed by the CAR[2] according to the water use downstream. In the following section existing limits, and water quality goals are described.

The proposed limits in this document go beyond those established by regional regulations, primarily in substances that prevail in the environment, such as Chromium and Chlorides. The effect produced by this type of contaminants prevails in the environment long term as a result of their accumulation.

As observed in section 2.3.2, the effect of the accumulation of chlorides in the soil is that these can affect the growth of plants and cellular activity. Using the water for crop irrigation will affect the economy of the inhabitants of the region, as is the case in the upper basin of the Bogota River. On the other hand, Cr^3 tends to precipitate and when discharged it will remain deposited in the sediment on the river bed. Over the long term, the effect of this accumulation has not been demonstrated, but taking into consideration the oxidation potential of Cr^3 to Cr^6 by the action of environmental agents *e.g.,* manganese oxide, and the toxic potential of Cr^6, this accumulation should be prevented, as it generates health risks for the inhabitants of the region and animal species.

2.4.1. Existing emission limits in the study region

Table 2 shows the existing variation in international norms that regulate tannery discharges, which vary according to the characteristics of the source receiving the effluents, whether salt or fresh. In Annex 1 a compilation of the existing international norms may be observed.

The CAR[2], in charge of regulating discharges in the Bogotá River and of guaranteeing the river's water quality in accordance with required standards for the use of water downstream -human consumption with treatment and restrictive irrigation- (CAR, 2006), fixed emission limits for the tanneries located in Villapinzón and Chocontá (CAR, 2004). As can be observed in Table 2, the tanneries should implement treatment systems in two phases, where initially they should comply with discharge characteristics for primary treatment and subsequently either individually or collectively, a secondary treatment focused on diminishing the load of organic matter.

The values fixed as a goal for the water quality of the Bogotá River is synthesized in the last column in Table 2.

[2] Corporación Autónoma de Cundinamarca CAR. Regional environmental authority in the study zone.

Table 2. Tannery emission limits: international (columns 3 y 4), regional (columns 5 y 6), and water quality goals for the Bogotá River (column 7)

Parameter	Unit	International regulation[3]		Regional Regulation[4]		Quality Goals Bogota river[5]
		Minimum (3)	Maximum (4)	Primary Treatment (5)	Secondary Treatment (6)	(7)
pH		5.5	9.5	5-9	5-9	
Temperature	°C	25	45			
SST	mg/L	30	200	1000	100	10
BOD_5	mg/L	20	300	200	60	7
COD	mg/L	100	500	400	120	
Sulfides (S_2)	mg/L	0.1	10	1	1	
Chromium (III)	mg/L	1	5			
Chromium (VI)	mg/L	0.05	0.5			0.05
Total Chromium	mg/L	0.2	2.5	<0.01	<0.01	
Chlorides	mg/L	100	4000	1200	1200	250
Ammonia (NH_3)	mg/L	2	100			
TNK (N)	mg/L	5	30			
Fat/oils	mg/L	5	100	30	30	
Total Coliform	MPN/ 100 ml			5000	5000	20000

Downstream from the effluent discharges of the tanneries, strawberry and potato crops are located. Water from the Bogotá River is used for irrigation of these crops, which may present problems due to the accumulation of chrome, chlorides and bacteria (Coliforms).

About 60 km from the tanneries' discharges the Tibitoc potable water treatment plant is located, which treats the water for human consumption of 30% of the inhabitants of Bogota, the capital city of Colombia. Cost overruns in the treatment of drinking water at the plant was valued at COL$5,470 million in the year 2002, corresponding to €2,400,000 (DNP, 2004). Cost overruns of the water treatment is not only associated to the tanneries, but to all discharges into the river occurring in the upper basin.

3. Methodology.

The methodology of the research is summarized in Figure 1, which shows the steps developed in order to reach the specific objectives.

[3] Annex 1. A compilation of International regulation and its sources is given.

[4] At the Upper Basin, two scenarios are defined for achieving emission limits: at first, individual treatment systems, and secondly, a collective treatment. Both are in line with a gradual accomplishment, in which tanners can afford the costs of compliance (CAR, 2004).

[5] Water quality goals for Bogotá River, Upper Basin, to be achieved by 2020 (CAR, 2006).

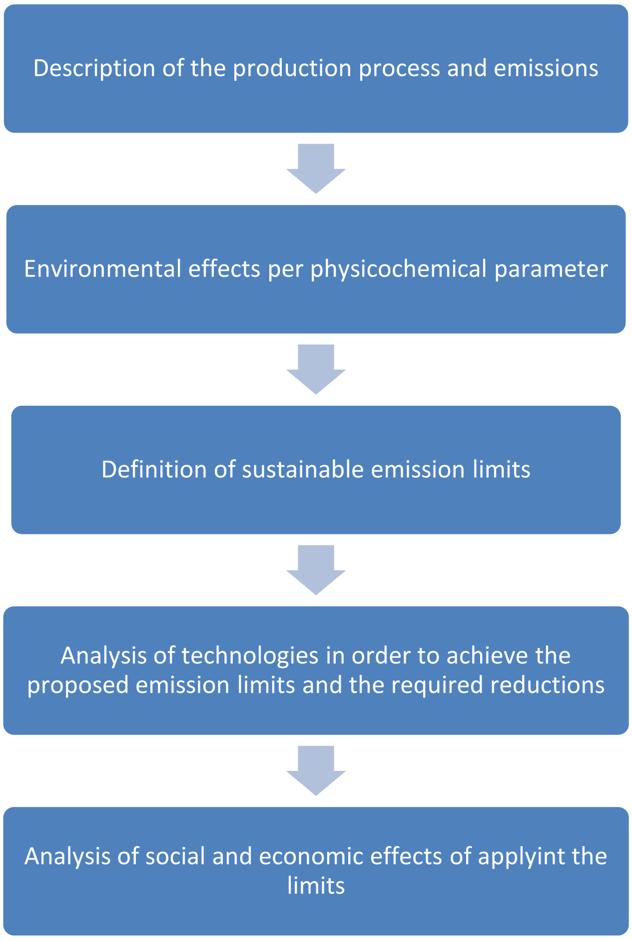

Figure 1. Methodology

3.1. To develop sustainable emission limits for the tanning industry.

1. Description of the production process and emissions. An archival research was carried out regarding the different stages of the tanning process, the chemicals used in the process, emissions and the final disposal of waste. (CCB, 2005; ACERCAR, 2001).

2. Environmental effects per physicochemical parameter. Subsequently, a literature review was conducted on the characteristics of the principal chemicals used in the industry and their potential environmental and ecotoxicological impact. Water quality parameters were studied, with the aim of identifying those that the system is not able to assimilate and transform, that is that are not considered sustainable in the long term.

   In order to analyze the collected information, a comparison was undertaken of the limits on discharges of effluents by the tanning industry proposed by different legal frameworks.
   With the above information, sustainable emission limits were defined for the tannery industries.

3.2. To define the gap between the emissions of a conventional tanning industry, the defined sustainable emission limits and the emission reduction options for the process.

A literature review was conducted regarding possibilities for improving the process and diminishing the contamination in order to achieve the proposed emission limits. Those alternatives were considered that present the greatest reductions and that have been accepted by the comminity of tanners in the study region.

Reductions on contaminant load are calculated according to the percentages obtained in prior research, first with respect to improvements in the production process and subsequently with end- of-pipe alternatives.

The gap is obtained from comparing the contaminant loads defined in set limits, with calculated contaminant loads following reductions with the existing technology.

3.3. To describe the long-term consequences of applying sustainable emission limits.

The possible economic and social impacts of defining and implementing sustainable limits are listed at regional and local level:

1. Regional level: the costs of treating water in the basin for human consumption at the Tibitoc plant are analyzed.
2. Local level: the individual costs of treating the water at each tannery and the collective biological treatment required to reach the proposed limits are analyzed.

Finally, a strategy was devised to be adopted in order to achieve the adoption of the proposed limits.

4. Results.

4.1. Sustainable emission limits for the tanning industry (listing of the limits).

Emission limits are defined in order to mitigate the environmental impact due to industrial emissions. There are two ways of establishing them:

1. Based upon standards widely adopted and that have been demonstrated to be suitable. However, this method can ignore individual situations and possible long term effects.

2. Based upon *in situ* studies, simulating the behavior of the polluted substance in the water body through transport processes (*e.g.,* advection, dispersion) and changes in different water quality parameters. So that water flow dynamics downstream of the discharge point can be understood, taking into account the stream's capacity for self-recovery . Emissions limit values are established in terms of the required water uses.

In order to establish sustainable limits, different factors must be taken into account such as available technology, economic conditions and the consciousness level of the industry's community regarding the risks they can generate and their responsibility as polluters.

The limits are defined taking into consideration the capacity the environment has to assimilate them according to the proprietary characteristics of the receptor and according to the type of contaminant. If the contaminant accumulates in the sediment, animals or plants, it should not be discharged into a natural channel as in the long term there will be a high concentration resulting from constant exposure to the compound. For this reason, Chromium and Chlorides' limits are set at 0 mg/l.

Once the process and waste characteristics have been reviewed, reference emission limits are proposed, with an emphasis in lowering the ocurrence of long term effects.

The limits are established per ton of raw hides. In water, a water consumption of 25 m^3 per ton of raw hides is assumed, as this is the maximum volume measured in tanneries with an efficient water use program (European Commission, 2009).

Permissible value limits proposed for tannery effluents are (Table 3):

pH: (6.0-8.5): It is important to include the pH in this list as there are some species that are sensitive to their variations. Tannery effluents have pH variations between 4 to 11, which should be controled prior to being discharged. Values lower than 6.0 are considered to increase the risk of Hydrogen Sulfide production, while those above 9.0 increase the risk of Chromium $^{+3}$ and Chromium $^{+6}$ oxidation (Bosnic *et al.*, 2000).

Maintaining a level close to neutral allows small fluctuations avoiding altering the balance of aquatic life. Effluents with levels of 6.0 – 8.5 are acceptable for irrigation (Australian Environment Act, 1997). If the pH exceeds 8.5 there is a rapid increase of ammonia in water in a non ionized form that is toxic to fish.

Temperature <30°C: At lower temperatures, reactivity of chemical compounds dissolved in the water body and the oxygen consumption of aquatic species is decreased. International legislations use this value in the majority of countries reviewed (Bosnic *et al.*, 2000).

BOD: ≤1.5 kg/Ton: BOD does not directly affect human health in its consumption, nevertheless the presence of high loads of organic material and anaerobic conditions in water, favor the growth of pathogenic microorganisms that lead to diarrheic and parasitic diseases in humans (Bosnic *et al.*, 2000).

COD: ≤**3** kg/Ton: This value indicates a moderate presence of dissolved reducing substances in the effluent without altering aerobic conditions in the water body (Bosnic *et al.*, 2000).

Total Suspended Solids: ≤2.5 kg/Ton: this value lessens the formation of mud. Mud diminishes the exchange of oxygen in water body's bed (Bosnic *et al.*, 2000; IUE, 2001). A low concentration of suspended solids in water also avoids later operational problems in irrigation systems and the closing of the soil's pores (Australian Environment Act, 1997).

Sulfides S^{2-}: ≤ 0.03 kg/Ton: Sulfur compounds in an oxidation state 2^- (in dissolved form) are common in residual industrial and domestic waters. The concentration of S^{2-} should be lower than 1 mg/L, so that, if increase the pH more than 10, the generation of high concentrations of Hydrogen Sulfide which poses an important toxic effect for human health will not take place.

Sulfates (SO_4^{2-}) ≤12.5 kg/Ton These are compounds derived from the use of Sulfuric Acid and products with a high Sulfate (Sodium) content. Effects of Sulfates on human health are given by its temporary laxative effect at high doses. Infants, the elderly or handicapped are sensitive to high doses of Sulfates in drinking water (greater than 500 mg/L) (EPA, 2003).

Fat and oils: ≤2.5 kg/Ton: Fat and oils form a film on surface waters, which inhibits the gaseous exchange of oxygen with the air, reducing the demand of oxygen by the dissolved microorganisms in the water (COTANCE, 2002; European Commission, 2003).

Ammonia NH_4^+≤0.03 kg/Ton: This value avoids the rapid growth of aquatic plants (eutrophication) and reduces the large consumption of oxygen necessary for its degradation, by which the aerobic conditions of water improve. Greater concentrations of ammonia favor its decomposition to NH_3, a toxic substance for fish (World Bank Group, 2006).

Nitrates NO_3 ≤1.25 kg/Ton: Nitrates are considered a risk for human health in values greater than 10 mg/L and greater than 30 mg/L in animals, as it produces metahemoglobinemia in vulnerable populations (infants under six months of age or congenital malformations of the hemoglobin) (Australian Environment Act, 1997; OMS, 2003; ATSDR, 2005).

Non-sustainable flows.

Total Chromium: 0 kg/Ton: The value of total Chromium, that is, Chromium in all its forms should be fixed at 0 in order to avoid its accumulation in the environment. This compound if found as Cr^{+3} tends to accumulate in sediments and be carried throughout the food chain generating subsequent problems in animals and plants.

Chlorides 0 kg/Ton: During the tanning process a high volume of chlorides is produced. Values between 250 and 1000 mg/L make water acceptable for human consumption but values greater than 500mg/L in irrigation water causes a reduction in productivity in the long term.

Chlorides accumulate in the soil producing problems in the long term (Romero, 2000), reason for which it is proposed that this limit be set at 0. To reach this emission limit, changes should be generated in the leather hide processing chain. In the slaughterhouses, the animal skin is salted for transport purposes and is stored prior to treatment.

Table 3. Proposed emissions limits for tanneries.

PARAMETER	Emission Limits (mg/L)	Load (kg parameter/ Ton raw hide)
pH	6.0-8.5	6.0-8.5
Temperature	30	30
BOD_5	60	1.50
COD	120	3.00
Total Suspended Solids	100	2.50
Sulfides	1	0.03
Sulfates	500	12.50
Fat & Oils	100	2.50

PARAMETER	Emission Limits (mg/L)	Load (kg parameter/ Ton raw hide)
Ammonia NH_4^+	1	0.03
Nitrates NO_3^-	50	1.25
Total Chromium	0	0.00
Cr^{6}	0	0.00
Chlorides	0	0.00
Water consumption	15-25	25 m^3/ton

4.2. Emission reduction in the tanning industry.

4.2.1. Average emission values in a conventional process.

The existing tanneries in the region of Villapinzón and Chocontá, waste without treatment and with seasonal fluctuations as the processes are not continuous. In a conventional process without treatment, the water is discharged once each process is finished, with diverse determinants of water quality according to the stage in progress.

Solid waste are deposited in the soil or in the river without any kind of treatment.

In the majority of tanneries finishing leather processes are not carried out, reason for which no atmospheric emissions are produced.

Figure 2 presents the inputs and outputs per each conventional production process stage. Average results from 17 water quality features and the average value of solid waste measurements in 6 tanneries that are part of the project are shown (CCB, 2005).

The standard deviation (STD) is high for some physiochemical parameters due to the differences inherent in the process, such as type of skin processed, input products utilized at each tannery and their quantity.

Figure 2. Input and Output in the process of tannery, posible reduction with process improvement and final treatment.

CONVENTIONAL PROCESS					POSSIBLE REDUCTION WITH PROCESS IMPROVEMENTS		
Input	Stage	Output			Process improvement	Reduction	Remainly output
		Parameter	Kg /ton hide	STD	References		Kg /ton hide
Salt	Beamhouse	BOD	793	212		50%	396
Moisturizers,		COD	1,032	193	Ecological unhairing. (Aloy et al. 2000; European Commission, 2001)	50%	516
Detergents,		TSS	840	400		50%	420
Sodium		S2	87	29		60%	35
Lime		F & O	29	14		50%	14
Bactericides		TKN	4	1		70%	1.26
Desinfectants		Cr Total	0.02	0			0.02
Water		Cl	371	526	Use fresh hides	100%	-
		Water comsuption	34,000	-	Unharing bath recyclling. (Nazier et al, 2006)	60%	13,600

CONVENTIONAL PROCESS					POSSIBLE REDUCTION WITH PROCESS IMPROVEMENTS		
Input	Stage	Output			Process improvement	Reduction	Remainly output
		Parameter	Kg /ton hide	STD	References		Kg /ton hide
		Salt	15.62	3.52			15.62
		Defleshing fat	341	56.59	Compost (European Commission, 2009)	100%	-
		Hair	24.3	6.68		100%	-
Formic acid	Tanning	BOD	1.08	0.15			1.08
Sulfuric acid		COD	5.86	2,87			5.86
Ammonium		TSS	2.49	3.21			2.49
Sulfate		S2	0.00	-			0.00
Sodium		F & O	0.08	0.10			0.08
Bisulfite		TKN	0.02	0.02	Deliming with nitrogen free products (Ludvik, 2000)	95%	0.00
Solvents		Cr Total	3.10	1.89	Recycling Cr baths, Cr exhaustion (EPA, CIATEC AC 2006)	80%	0.62
Cr		Cr 6	0.00	-			0.00
Sodium bicarbonate		Cl	37.68	22.63	Pickling without salt. (Aloy et al, 2000)	80%	7.54
Magnesium oxide		Water comsuption	2,666	-	Recycling Cr baths, GOP (European Commission, 2001)	90%	266.61
Sodium carbonate		Cr shavings	72	30.95	Leather fibre borad production, (European commision, 2009)	100%	-
Chromium sulfate	Retanning Dyeing	BOD	1.94	0.73			1.94
Organic acids		COD	3.67	1.47		90%	0.37
Coloring agents		TSS	2.41	3.46			2.41
Animal oil		S2	0.20	0.01			0.20
		F & O	1.42	1.96	High exhaustion of dyes , fatliquors and agents during post tanning operation (European Commission, 2009)		1.42
		TKN	0.02	0.02			0.02
		Cr Total	0.16	0.20			0.16
		Cl	3.33	3.56			3.33
		Water comsuption	3,334	-			3,334
		Trimmings	31.55	27.07		100%	-

POSSIBLE REDUCTION WITH FINAL TREATMENT			
Parameter	Homogenized effluent Kg /ton hide	Primary +Biological nitrification, desnitrification treatment (European commission, 2009)	Remainly output Kg /ton hide
BOD	314	98%	6
COD	408	95%	20
TSS	333	98%	7
S2	27	98%	0.55
F & O	12	90%	1.17
TKN	1.00	98%	0.02
Cr Total	0.06	100%	-
Cr 6	0.00	100%	-
Cl	0.76	0	0.76
Water comsuption (L)	17,200		17,200

4.2.2. Existing technology to achieve emission limits.

In order to achieve the proposed sustainable emission limits a strategy is required that integrates the optimization of the process, the treatment of effluents and the integration of the production chain. Cleaner production is the strategy aimed at the continuous improvement of the processes, the optimization of the use of chemical inputs, the substitution of inputs by others less contaminating, the efficient use of water and energy.

In order to reach the proposed emission limits the commitment of business owners and the training of employees is essential for the improvement of the environmental performance of the industries. In addition, actions should be undertaken which accompany the technology to improve the environmental performance and that are included in the proposed strategy to achieve the limits (section 5.4). Figure 2 summarizes the possible value to which the physicochemical parameter can be reduced if improvements to the production process and the final treatment of emissions are implemented.

The alternatives presented are those that have been studied and can produce the greatest reductions with respect to pollution (European Commission, 2009). The costs of implementation and operation are affordable for the business owners of the study zone, and the implementation of this strategy has been initiated in the tanneries.

4.2.3. GAP analysis.

The Gap analysis is performed to estimate if it is possible to reach the proposed limits according to the existing contaminant reduction options.

Table 7 summarizes the liquid and solid emission values in a conventional process, the final load expected once improvements to the production process and to the final treatment are implemented, and the proposed limits with the aim of comparing which emission can comply with the proposed limits.

In order to achieve the limits, improvement of the final treatment carried out with the residual water is required to reduce the organic load, i.e. BOD, COD, TSS. Chlorides will also not achieve the proposed limit and a reduction of their use in pickling, or the testing of possible end-of-pipe treatments is required.

Solid waste can be appraised and comply with the proposed limit of 0 emissions, except sludge from the treatment plant.

Table 3, Current load, final load after CP implementation and limits.

WASTE WATER

PARAMETER	Actual load	Load after improvement and final treatment	Limits
	Kg/Ton raw hide	Kg/Ton raw hide	Kg/Ton raw hide
BOD	796	6.28	1.50
COD	1042	20.41	3.00
TSS	845	6.66	2.50
S2	87	0.55	0.03
F & O	30	1.17	2.50
TKN	4.2	0.02	
Cr Total	3.3	0.00	0.00
Cr 6	0	0.00	0.00
Cl	412	0.76	0.00
Water comsuption (L)	40000	17200	25000

SOLID WASTE

PARAMETER	ACTUAL DISCHARGE	DISCHARGE AFTER CP	LIMITS
	Kg/Ton raw hide	Kg/Ton raw hide	Kg/Ton raw hide
Salt	15.6	0	0
Defleshing fat	341	0	0
Hair	24.3	0	0
Cr shavings	72	0	0
Trimmings	31.6	0	0
Sludges for waste water treatment	NI*	0	0

*NI: No information available

4.3. Long term consequences.

To achieve the emission limits with the proposed sustainability criteria, it is first necessary to implement CP in the businesses in order to reduce the contaminant load and improve the production process by making it more efficient. By implementing CP the volume of solid residues generated will increase and alternatives should be studied to take advantage of these sub-products. The increase is due to the fact that some of the alternatives reduce the contaminant load in the water by filtering it, i.e. Unhairing with hair immunization. Hair will be a new residue that should be appraised.

Subsequently primary treatment systems should be constructed.

The secondary treatments, being expensive, should be constructed collectively and should be operated by trained personnel.

To substitute the use of Chlorides, primarily for the preservation of the animal skins, work should be undertaken at the previous stage of the production chain; that is the slaughterhouses so that the animal skins are sent to the tanneries fresh, with the addition of other types of chemical inputs that avoid putrefaction and that are biodegradable or by freezing the skins.

Solid residues should be segregated in the industry for subsequent appraisal. The appraisal of solid residues should be collectively sought after in the long term, as the technologies are expensive and technical know-how is required for its operation.

5. Discussion.

5.1. Sustainable emission limits (comparison with national and international legislation).

Existing regulations for the effluents from tanneries discharges have widely distinctive characteristics depending on the following factors:

1. Type of discharge: If discharge is made to a water body or is stored in a collector for further treatment.
2. Characteristics of the receiving water body (e.g. self purification ability of the stream, salinity, water flow).

Table 2 shows international regulation limits (as ranges), which can be detailed in Annex 1, the currently defined limits established by CAR for tanneries, water quality goals for the Bogota River by 2020 (CAR, 2006) and the sustainable emissions limits proposed by the SWITCH-IDEA team (Table 3).

The proposal with respect to the establishment of the limits is that compounds that the environment cannot biodegrade by natural processes should not be discharge and accumulate forever, that is, Chlorides and Chromium.

Emission limits for effluents are determined in terms of contaminant load, with the aim of establishing control over the water volume consummed and to reduce pollution, avoiding dilution. Solid residues are established at 0, as it is possible to reuse them in other production process.

5.2. Reducing the emission of tanneries (awareness, financial aspects, CP, etc.). Cost analysis of implementing alternatives.

In order to reduce emissions in the tanneries, the commitment of business owners is essential. Likewise, the training of the operators is required so that the identified techniques and technologies for improving the production process are successful.

Tanners at Villapinzon have learned production procedures from their predecessors, have low schooling and scarce knowledge of the basic tanning chemistry. For these reasons, changing production processes depends on their consciousness about environmental care, on knowledge transfer and on the adoption of a continuous improvement strategy that allows tanners to see the economic benefits of CP implementation.

They must build efficient primary treatment systems in their industries, in such a way that BOD, TSS, Cr, S can be reduced and effluents are delivered under standardized conditions to a secondary treatment which otherwise will not function adequately.

Constructing and operating treatment systems is expensive. Some of the region's tanners have enough resources to establish a primary treatment system. But as for secundary treatment, resources and technical support are clearly out of the reach for most of them, which suggests that a joint secondary treatment system would be a sound option for achieving proposed sustainable limits.

Solid wastes are brought to a landfill or simply dumped in any empty place without any treatment. Most of them can be used as raw materials for other production processes (as hair can be composted). Individual solutions for solid waste management are not financially sustainable. Instead, the industries can learn to face a collective strategy for the solid waste valuation that is technologically sound and that meets market needs.

All additional costs included in the production process, such as substitution of chemical inputs, treatment of wastewaters and the valuation or disposal of solid residues, should be transferred to the buyers in order to ensure the maintenance of the businesses in the market. Therefore, a market is required that pays for additional costs of the good environmental management.

The average cost of investment for improve the production process and treatments of waste water and solid waste are summarized in Table 4. The operational costs per kilogram of finished product without CP is 5.7€ and with CP is 6.3€ .

The production cost for the tanneries will be increased. This is one of the reasons why the tanners still have not invested in this infrastructure, which is required by law.

Table 4. Investment for individual al collective investment.

Activity	Investment value per **tannery €**	Investment for 170 tanneries Collective **investment €**
Process improvement		
Recycling chromium baths	3.000	510.000
Ecological unhairing with hair immunization	1.500	255.000
Recycling unhairing baths	5.000	850.000
Wastewater treatment		
Primary treatment	30.000	5.100.000
Operational cost in 1year	2.341	398.000
Secundary treatment		300.000
Operational cost in 1year	3.456	587.520
Total	45.297	7.413.000

Downstream of the tanneries, the river water is used for human consumption and irrigation. The cost of the treatment to improve the water quality of the river is shifting to society, as it is paying for the water treatment in order to have drinking water with inferior quality conditions due to the effluents being discharded from the tanneries. (DNP, 2004). Cost overruns at the Tibitoc drinking water treatment plant in 2004 were in the amount of 2,400,000 € (DNP, 2004). Although not all plant cost overruns are attibutable to the contamination caused by the tanneries, the water quality will improve if emission limits are implemented. The investment would be recovered in the short term.

5.3. Long-term consequences (both the limitations of reality but also showing environmental/public health benefits, real cost benefit analysis).

Achieving sustainable emission limits in the long term guarantees the different needs for water use along the basin for regional requirements (human consumption, irrigation, recreation). Current conflicts due to water use will diminish and the tanners' image will be improved. Through CP implementation, the health risk hazard will decrease, tanneries productivity, competitiveness and quality of life will increase.

Adopting these limits must be a gradual endeavour, as tanners do not have the technical or the financial support for implementing CP. The process changes must be jointly conducted with training and environmental education. They must also be led to environmentally conscious markets, searching for higher economic profits.

Tanneries that do not abide by environmental regulations will disappear due to government pressure. Forced closures have already impacted the social and economic regional conditions since more than 4,000 people have this activity as their earning source. Tanning is the second most important economic activity in the town.

As a final step, in order to abide by the law, a secondary treament is needed. No single tannery has the financial resources or the technical background to operate it correctly and individually. A collective solution should be adequately supported by involved institutions.

Investing in any new technology will result in additional costs that currently tanners cannot afford. If externalities, and the higher costs for water treatment downstream were considered, efforts for CP implementation would become cost-effective throughout the region.

To reach zero emissions of chlorides it is necessary to develop a joint strategy along the productive chain (tanneries with slaughterhouse).

The collective work of business owners is required in order to carry out research and to implement options of solid residues that are sustainable. In this manner, over the long term these business owners will have another source of income by exploiting the solid residues.

5.4. Strategies for implementing sustainable emissions in the tanning industry.

The strategy consist of defyning the steps required in order so that proposed emission limits are complied with in the long term. In the following numerals required actions in the short, medium and long term are described in order to reach the proposed limits, in accordance with the study region characteristics.

Short term

1. Environmental awareness
   Tanners should have awareness about the environmental effect generated by the production process and seek to control and reduce it. The awareness should be reflected in a commitment to improve their environmental performance and to reach the proposed limits.

2. Management and good housekeeping:
   - Monitoring: process input and outpus measurements. Process documentation.
   - Reduction in the consumption of supplies: Control of chemicals, water and energy in accordance with the final product. Define a process control system in order to assure the quality of the product.
   - Segregation of emisions: Separation of effluents and solid waste according to their characteristics in order to enable their reuse and recycling.
   - Training of personnel: In order to achieve an improvement in the environmental performance, the training of personnel in environmental topics and in the production process is required.
   - Equipment maintenance: equipment should be checked to assure efficiency and safety.

3. Environmental management
   Identifying those responsible for the environmental management in the tannery is recommended; so that these persons may maintain management updated with respect to cleaner production technologies that can aid in reaching set emission limits.

4. Substitution of chemical inputs:
   The environmental performance of the tannery can improve if some chemical inputs are changed in accordance with the final product. Some of the recommended substitutions are found in Figure 2..

5. To use batch instead of running water washes

6. Preference for fresh skins to salted ones. Integration of the production chain so that slaughterhouses supply fresh skin directly to the tanneries, and in this way avoid preservation with the use of salt.

Medium term

1. Undertake adaptations in order to implement the reuse and recycle of water
2. The construction of an individual residual water primary treatment plant, keeping in mind the reduction for process improvements and recirculations.
3. Research of appraisal options for solid residues according to regional market characteristics and technologies available.

Long term

1. Collective construction of a biological treatment system in order to reach the proposed limits.
2. Collectively to implement solid residue appraisal and exploitation alternatives.

6. Conclusions.

This research contributes towards generating sustainable emission limits the tanning industry. They are set according to the nature of the components, their long -term consequences, and the capacity of the environment and the receiving body to assimilate them. If the contaminants are not engaged in a natural cycle that assimilates them, these should not be discharge in the environment.

The gap between conventional emissions, improvement options to the process and final treatment and proposed limits was obteined. In order to reach the proposed limits, the commitment of business owners is required as well as the training of personnel to manage the existing alternatives. Additionally, to achieve the proposed limits, collective solutions are required in order to manage solid residues and the secondary treatment of effluents. The production chain should also be integrated to reduce Chlorides emission and in order to improve the enviromental performance of the tanneries,

The consequences of implementing the set limits over the long term are described. Water in the Bogotá River Basin may be used for current uses (irrigation and human consumption). By guaranteeing that there will not be emissions from solid residues, the exploitation of these residues is fostered, which will generate additional income for the tanners.

It is proposed that the enforcement of sustainable emission limits be a gradual endeavour, based upon the technological level and the social and economic conditions prevailing at each location.

7. Recommendations.

Environmental authorities must carry out follow-up not only with respect to waste water parameters, but also regarding chemical use and formulations.

Associative work is needed to add value to solid wastes and to install secondary treatment facilities. Many institutions must be involved in supporting these efforts.

It is more cost effective to deal with pollutants at the source than building multiple wastewater treatment solutions downstream. By doing this, multiple water uses are assured and health hazards are avoided.

Given the relevance of the tannery sector for the regional economy, the difficulties regarding CP uptake,the implementation of treatment systems, and the national importance assigned to the recovery of the Bogotá River, a joint work effort is needed between all the stakeholders involved.

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UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE BOGOTÁ

D421. Sustainable industrial emission limits for tanning industry

ANNEX 1: LIMITS FOR DISCHARGING TANNERIES EFFLUENTS INTO SEWAGE AND WATER BODIES

INSTITUTO DE ESTUDIOS AMBIENTALES– IDEA

COUNTRY	ARGENTINE		AUSTRALIA		AUSTRIA		BRAZIL		CHINA	
PARAMETER	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*
1.pH	5.5-10	5.5-10	6.0-9.0	6.0-10.0	6.5-8.5	6.0-9.5	5.0-9.0		6.0-9.0	6.0-9.0
2. Temperature °C	45	45	45	38	30	30	<40	40		35
3. Suspended Solids			60	*	30	150			70-150	400
4. Settling Solids	0.5	0.5					1.0			10
5. BOD5 mg /l	50	200	40	*	25		60		20-100	600
6. COD mg/l	250	700			200					1000
7. Sulfides mg S-2/l	1	1		1 A 5	0.5	2	1	5	1	10
8. Chromium (III) mg/l	2	2			4	40		5	1.5	2.0
9. Chromium (VI) mg/l	0.2				0.1	0.1	0.5		0.5	0.5
10. Total Chromium mg/l	2	2	0.3	1 A 20	1	1	2.5		1.5	1.5
11. Chlorides mg/l	*	*	*	*						
12. Sulfates mg/l	*	1000		1500						
13. Ammonia mg N/l	3	10		50-200			5			
14. TNK mg N/l	10	30					10			
15. Fats/oils mg/l	100	100		100-1000			20 A 30	100	10 A 15	100
16. Phenols mg/l	0.5	0.5	0.05	10 A 100			0.1-0.5		0.5	2.0

COUNTRY	COLOMBIA		DENMARK		EGYPT		FRANCE		GERMANY	
PARAMETER	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*
1.pH		5.0-9.0	6.5-8.5	6.5-9.0	6.0-9.0	6.0-9.0	5.5-8.5	6.5-8.5	6.0-8.5	6.5-9.0
2. Temperature °C	40		30	35			30	30		35
3. Suspended Solids		1000	30				30-100	600	20-25	
4. Settling Solids					200	200				
5. BOD5 mg /l		500			500	500	40-200	800	20-25	
6. COD mg/l		1000			100	100	125	2000	200	
7. Sulfides mg S-2/l			2		10	10	2	2	1	2
8. Chromium (III) mg/l							1.5	1.5	1	
9. Chromium (VI) mg/l							0.1	0.1	0.05	0.5
10. Total Chromium mg/l		0.5	0.2	2	1	1	1		1	2
11. Chlorides mg/l							30-100	500		600
12. Sulfates mg/l			300							600
13. Ammonia mg N/l			2.0		100	100			10	*
14. TNK mg N/l			5				30	150		
15. Fats/oils mg/l		250	5		100	100				*
16. Phenols mg/l							0.1	0.1		*

COUNTRY	INDIA		ITALY		JAPAN		KENYA		MEXICO	ZEALAND
PARAMETER	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*
1.pH	5.5-9.0	5.5-9.0	5.5-9.5	5.5-9.5	5.0-9.0	5.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0
2. Temperature °C	40-45	40-45	30-35	30-35			25			55
3. Suspended Solids	100	100	40-80	200	200	200-300	30	300	200	
4. Settling Solids									5.0	
5. BOD5 mg /l	30	500	40	250	160	160	20	450	200	
6. COD mg/l	250	250	160	500	160	160				
7. Sulfides mg S-2/l	2	2	1	2	2	2			0.1	1 A 5
8. Chromium (III) mg/l	2	2		4						
9. Chromium (VI) mg/l			0.2	0.2					0.1	
10. Total Chromium mg/l	2	2	2	4	2	2	1		1	5 A 50
11. Chlorides mg/l			1200	1200				3000		
12. Sulfates mg/l	1000	1000	1000	1000				100		
13. Ammonia mg N/l	50	50	10 A 15	30				100		
14. TNK mg N/l										
15. Fats/oils mg/l	30-100	30-100	20	40	30	30-50	TRAZAS	100	30	
16. Phenols mg/l	5 A 50	5 A 50	0.5	1	5	5	2			

COUNTRY	NICARAGUA		PAKISTAN	SPAIN		SWITZERLAND		UNITED STATES		TURKEY		UNITED KINGDOM	
PARAMETER	*Surface water*	*Sewage water*	*Surface water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*	*Surface water*	*Sewage water*
1.pH	6.0-9.0	6.0-10.0	6.0-9.0	5.5-9.5	8.0-10	6.5-8.5	6.0-9.5	6.0-9.0	6.0-10.0	6.0-9.0	6.0-10.0	6.0-9.0	6.0-10.0
2. Temperature °C			40	30		30	40				40	25	40
3. Suspended Solids	150	400	200	80-300	500-750	20		60		150	350		
4. Settling Solids	5			0.5-2								30-50	500-1000
5. BOD5 mg /l	120	400	80	40-300	750-1000	20		40		100	250	20-30	
6. COD mg/l	250	900	150	160-500	1500-2500					200	800		2000-6000
7. Sulfides mg S-2/l	0.2	5	1	1 A 2	1 A 20	0.1	1		24	1	2	1	2 A 5
8. Chromium (III) mg/l				2 A 4		2	2		8.0-19			2 A 5	10 A 35
9. Chromium (VI) mg/l		0.5		0.2 - 0.5	0.5	0.1	0.5		0.5	0.3		0.1	0.1
10. Total Chromium mg/l	10	3.5	1	2	3 A 5	2	2	1	8.0-19	2	5	1.0-2.0	1.0-20.0
11. Chlorides mg/l		1500	1000	2000	2000	200						4000	5000
12. Sulfates mg/l		1500	1000	2000	2000		300				1700		1000-1200
13. Ammonia mg N/l			40	15-50	85							100	10-100
14. TNK mg N/l											100		
15. Fats/oils mg/l	30	150	10	20-40	150	20				20	100		50-500
16. Phenols mg/l	0.1	1	0.3	0.5-1	2	5	5		10		10		

*** SPECIFIC REQUIREMENTS HAVE BEEN SATISFIED**

Source:Based on values compiled by Bosnic M., Buljan and Daniels R.United Nations Industrial Development Organization (UNIDO). Regional Programme for Pollution Control in the Tanning Industry in South East Asia. Pollutants in Tannery Effluents. August 2000. 1-26. y www cepis.org.pe. Pollution limits for discharge of tannery effluents into water bodies and sewer. Página consultada. 10-01-2007