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Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

D.427. Description of the demo process for the composting of hair from the de-hairing process and fleshings from the liming process, including the results of the environmental and economic impact assessment and the knowledge transfer process

D4.2.5.a	Description of the demo process for the grease valuation and for the composting of hair from the de-hairing process
D4.2.7.a	Report on tannery de-hairing process product development describing the characteristics, design, cost evaluation, business feasibility and green seal rating of the product
D4.2.7.b	Report on tannery hair marketing process including the results of the environmental and economic impact assessment and the knowledge transfer process

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SWITCH Document:

Description of the demo process for the composting of hair from the de-hairing process and fleshings from the liming process, including the results of the environmental and economic impact assessment and process of knowledge transfer

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Audience

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

Purpose

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

The research objective is to reduce pollution levels in the tanneries' zone at Villapinzón and Chocontá (Colombia), by recycling solid waste from tanning (operation processes through composting).

Background

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

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

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

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

any treatment.

At present there are few residue valorization alternatives being implemented. Some tanneries carry out a non-technical composting or sell some residues, but the majority disposes of them without any prior treatment directly onto the soil or waterways, others burn the residues without any controlling the gases generated. Occasionally, business owners pay for the disposal of their residues in safety cells in sanitary landfills.

With regard to studies undertaken in the sector, starting in the year 2007, the waste of each tanning process was identified, along with applicable and available techniques for its reuse. An experimental study was conducted of composting of de-hairing waste (Cuervo, N. 2008), this study concluded that composting is a technically and environmentally feasible technique for reusing de-hairing wastes.

Potential Impact

It is calculated that there exist 184 tanneries in Villapinzón and Chocontá, which annually produce nearly one hundred thousand skins and generate around 3,700 tons of hair and 7,200 tons of fleshings. With this project the aim is to reduce the environmental impact originated from the accumulation of these two residues on the agricultural soil and the waterways. From the start of Project SWITCH 30 tanning businesses have allied in order to carry out the recovery of 2,400 tons of hair and fleshings annually, producing a compost that contributes nutrients to the soil and improves its structure.

Recommendations

- Tanners should be committed with the implementation of the residue recovery plant.
- In order to assure an adequate implementation of the composting process, the tanneries should implement technologies, better operational practices and improvements to the dehairing process with hair save.
- The defleshing subsequent to the liming operation should be gradually changed for green defleshing or prior to dehairing. In this way the fleshings may be recovered for the extraction of the grease.
- All residues should be gradually integrated to the leather production chain to give it value and to generate profits for the industry in an associative manner.
- The regulatory framework cannot be an obstacle for the improvement process of these tanneries. The focus should pass from the current sanction oriented one to one of "walking with" the industries in a continuous fashion and to jointly determine the hazardous characteristics of the residues, in order to find feasible alternatives that contribute to the solution of the environmental contamination.

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1 INTRODUCTION

It is calculated that there are 184 tanneries in Villapinzón and Chocontá, which annually produce nearly one million skins and generate approximately 3,700 tons* of hair, 7,200 tons of grease from defleshing, and 3,700 tons of leather shavings. These residues on many occasions are disposed of directly on the ground or waterways, without prior treatment. Out of this group of tanneries there are 30 businesses interested in undertaking the proper management of their residues, which have been identified during the implementation of Project SWITCH.

In order to decrease the environmental impact of tanneries' wastes, some reusing techniques have to be adopted, as opposed to just sending these to sanitary landfills. From the different alternatives, composting was selected due to its technical, economic and environmental characteristics. For this reason the feasibility of the commercial initiative was studied with a description and analysis of entrepreneurial-associative perspectives, which allowed having a solid concept regarding compost production. This will facilitate to Asociación de Curtidores (tanners' association) de Villapinzón y Chocontá –ACURTIR ACURTIR the concrete steering of the commercial negotiation involved.

Based upon these results and taking into account that composting is a well-known technique, adaptable to different types of biodegradable waste, a pilot process was launched for composting hair, fleshing or chrome shavings in order to establish the operational conditions favorable for each type of composting in the particular zone where the tanneries are located. (Altitude: 2715 m above sea level and average temperature of 13 °C).

This report is in response to objectives 4.2.5.a, 4.2.7 a and b, aiming to reuse solid waste from the de-hairing operation, through developing a pilot project for making and selling compost as soil organic fertilizer from hair and fleshing wastes. In addition, chrome shavings are also evaluated. Since some tanners say that they have achieved the composting of such waste in order to reduce the volume of tanning residues, it is interesting to verify this process. Although the chrome shavings contain trivalent chromium to stabilize the proteins in raw skin hide indefinitely, which prevents its biodegradation.

This deliverable shows the development of the compost as a product obtained from residue generated during the dehairing process in the tannery. The characteristics of the residue and the product are described, a simple productive project design reviewing such issues as costs, business feasibility and type of green seal. Likewise it presents the results of the environmental impact evaluation and the knowledge transference process carried out.

2 OBJECTIVES, PRODUCT, AUTHORS AND ACKNOWLEDGEMENTS

2.1 Objectives

To reduce pollution levels in the tanneries' zone at Villapinzón and Chocontá (Colombia), by recycling solid waste from tanning (operation processes through composting).

* 1 metric ton (MT): 1000 kilogram

Specific Objectives:

- To describe a composting pilot project for unhairing and defleshing waste.
- To establish follow-up and control methods for the pilot process.
- To define the commercial requirements for compost in accordance with existing technical regulations.
- To try composting of chrome shavings in order to reduce its volume.
- Describe the dehairing and defleshing residues and determine the recovery alternatives for residues generated in these operations.
- Prepare a basic design for the residue collection and recovery plant
- Evaluate the business feasibility in market and environmental terms
- Identify and classify the finished product (compost) and identify the procedure required to obtain the green seal.

2.2 Product

A description of a pilot process adding value to fleshing and hair from the tannery process: product development, describing the characteristics of the product, design of the project, cost evaluation, business feasibility, green seal rating, marketing process including the results of the environmental and economic impact assessment and process of knowledge transfer.

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2.4 Acknowledgements

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3 BACKGROUND

The implementation of recovery alternatives for solid residues generated by the 30 tanneries associated to ACURTIR[1] is envisaged in the strategic Plan in the tanneries of Villapinzón: called competitiveness and innovation in the leather production chain "(Cleaner production, association building and development of alternatives in the management and recovery of Solid Residues)," specifically in goal number 2: To associate the tannery business owners with a solid residue valorization plant.

[1] Asociación de curtidores de Villapinzón y Chocontá – ACURTIR is a tanners' association

The successful selection and implementation of the residue recovery alternatives requires the application of a logical sequence of activities, as follows:

1. Identify, classify and quantify the residues generated.
2. Identify the recovery alternatives of each residue.
3. Evaluate the feasibility of each improvement alternative in accordance with the economic, environmental, technical and organizational factors.
4. Prioritize and select the alternative most suitable to the conditions and needs of the business owners.
5. Design and implement the selected alternative.

The execution of these activities required specific information provided by the tanners, who foresee that collectively approximately 30 active tanneries will be assisted, with an average monthly production of skins of 2,000 units each, for a total of 60,000 skins the equivalent of 1,340 tons of raw or green animal hide, which monthly generate 828 tons of impure salt, hair, fleshings, and chrome shavings.

To carry out the valorization of some of the residues generated by the tanneries in the study zone, the business owners acquired a piece of land where the selected alternatives will be implemented.

Currently, the residue valorization alternatives that are implemented are few; some tanneries carry out a non-technical composting or sell some of the residues. But the majority disposes of them directly onto the soil or waterways without prior treatment, others burn them without controlling the gases generated. Occasionally business owners pay for the disposal of their residues in safety cells of sanitary landfills.

With respect to studies undertaken in the sector, starting in the year 2007, the waste of each tanning process was identified, along with applicable and available techniques for its reuse. An experimental study was conducted of composting of de-hairing waste (Cuervo, N. 2008); this study concluded that composting is a technically and environmentally feasible technique for reusing de-hairing wastes.

4 SELECTION OF RECOVERY ALTERNATIVES

In selecting the type of recovery that would be implemented to each waste product, the methodology of multiple criteria analysis was applied (EuropeAid, 2005). During the evaluation of the alternatives the economic capacity and current production technologies of the region's tanneries were taken into account, as well as the cultural level and aspirations that the businesses have in order to estimate the degree of importance of the alternatives. See appendix A.

4.1 Identification of residues with greater feasibility of recovery

The residues with greater feasibility of recovery are those that can generate a greater environmental impact, their disposal has a high cost and/or the recovery alternatives bring an economic benefit with them, be that by not having to pay environmental fines, by reducing costs in the management of residues or by generating revenues from the exploited residues.

Table 1 shows the quantities of residues generated per ton of raw animal hide and by group of tanneries.

Table 1. Type and quantity of residues generated

Type of residue	*Quantity generated (Kg/Tm raw skin)*	*Average weight (Kg/Tm raw skin)*	*Monthly average weight 30 tanneries (Tm)*
Impure salt: collected before soaking. Contaminated with blood, grease, flesh, hair, soil and feces.	14 to 28	21	28
Hair: filtrated in dehairing. Contains Sodium sulfide and lime residues	120 to 185	152,5	204
Fleshings: trimmings generated in defleshing, after liming. Contains lipids and proteins. Contaminated with sodium sulfide and lime	200 to 385	292,5	391
Chrome shavings: generated from the shave of the chrome tanned leather. Mixed with wood sawdust.	20 to 285	152,5	204

Source: Technical Team IDEA-UNC

4.2 Selected recovery alternatives

Table 2 describes the current handling, the requirements of a cleaner production prior to the generation of and the valorization alternatives of each residue. These residues have a high content of humidity and should be packed separately in sackcloths, stored and allow the water to be drained in an adequate place with a liquid collection system and transport to a residual water treatment plant.

Table 2. Valorization alternatives and prior requirements

Type of residue	*Current Handling*	*Previous CP requirements*	*Selected alternatives*
Impure salt	Reused in salting of fresh skin or for brick production. It is disposed as a domestic residue.	Recovery of salt adhered to the skin (utilized for preservation)	Collection and sale to metallurgic, brick and chemical industry
Hair	Non-technical composting within the business. Delivery to third parties for compost processing.	Carry out the dehairing with recovery of the hair.	Production of fertilizer
Fleshing	Disposed of in the soil in agricultural production zones. Large chunks are sold as low quality flesh for the production of gelatin.	Eliminate the borders of the skin that are useless for the final product.	Production of fertilizer
Chrome Shavings	Some businesses sell it for the manufacture of reconstituted leather. The shavings combined with wood sawdust are deposited in the soil; it is generated by businesses that do not have drainer, and is deposited in agricultural use soil.	Carry out the operation of shave without contaminating the chrome shavings with wood sawdust, make use of a draining machine.	Sale to reconstituted or agglomerated leather, brick, or gelatin industry.

Following the realization of these evaluations, the composting alternative will be tested experimentally under real operation conditions in the Municipality of Villapinzón.

5 PILOT PROJECT WASTES COMPOSTING

This deliverable describes the pilot process for adding value to hair waste from the unhairing operation, to fleshing from defleshing and to chrome shavings (with sawdust) from the trimming operation. The first two wastes contain certain amounts of sodium sulfide and lime, but these compounds do not prevent the hair and fleshing to decompose.

First of all, drivers influencing composting are determined, after which variables to be controlled during the pilot composting process at the different stages are identified. Wastes and the manner these were collected from several tanneries are described, alongside with the applied technique for pile building. Then, follow-up and control methods are accounted for, with special reference to the physicochemical and microbiological parameters to be analyzed. The requirements for selling compost, derived from Colombian Technical Standards, are reviewed.

5.1 Composting Process

Composting is the biologically driven decomposition and stabilization of organic substrates under conditions that allow the development of thermophilic temperatures, as a result of biologically produced heat, and the recovery of a stable, pathogen-free product that can improve soil porosity, and therefore drainage, aeration, moisture holding capacity and that reduces compaction (Haug, R., 1993). According to its quality, compost can be used in a variety of applications: High quality compost can be used in agriculture, horticulture, landscaping and home gardening, medium quality as erosion control, and low quality as a landfill cover or in land reclamation projects (Dalzell et al, 1987).

The process of composting depends on the activity of microorganisms, which can exist in the material to be composted or added to it. Those microorganisms account for organic matter decomposition. In order to live and develop its decomposition activity, optimal conditions of temperature, moisture and oxygenation are required (Sztern, D. and Pravia M., 1999; Ryckeboer, J. et al, 2003; and National Resource Conservation Services-U.S., 2007).

5.1.1 Composting Process Description

Four composting stages are defined according to the temperature, which is directly proportional to the biological activity within the composting process. As the metabolic rate of microorganisms accelerates the temperature within the piles increases, then the temperature is a function of the accumulation of heat generated metabolically, and simultaneously the temperature is a determinant of metabolic activity. The interaction between heat output and temperature is the centerpiece of rational control of the composting process (Ryckeboer, J. et al, 2003). Stages are:

1. **Mesophilic**. At ambient temperature, mesophiles microorganisms rapidly multiply in vegetable mass. As a result of metabolic activity, temperature increases and organic acids are produced, lowering the pH.
2. **Thermophilic**. On reaching 40°C, thermophiles microorganisms begin their action, transforming nitrogen into ammonia, and the pH turns alkaline. At 60°C, those thermophile fungi disappear and sporigen bacteria and actinomycetes appear which decompose waxes, proteins and hemicelluloses.
3. **Cooling**. When temperature drops below 60°C, thermophile fungi re-invade humus and decompose cellulose. Below 40°C, the mesophilic activity re-starts and the pH slightly decreases.
4. **Maturing**. In a period of several months at ambient temperature, secondary reactions take place, mainly condensation and polymerization of humus.

According Hellinger, K. and Mühlbach, R. (1996) the compost involving the accelerated aerobic degradation of organic waste materials (hair or fleshing) by natural micro-organisms. In order to

grow, the micro-organisms need a specific carbon-nitrogen ratio in the substrate. The optimum value is approximately C:N = 25-35:1. In hair, this ratio is 3-4:1. This means that the hair has to be mixed with other waste materials which act as suppliers of carbon (sawdust or wood chips, household and garden refuse, etc.) The optimum water content in the composting mixture is approximately 50%. Hair which has not been degraded is useful because it endows the compost with a long-term effect.

In a Swedish tannery, a mixture of the following composition is being composted in windrows: 4.5 % drained hair, 14.5 % drained fleshing, 6 % municipal sludge and 75 % wood chips and bark.
Temperatures in the windrows reach 80°C within a few days, and after two months the windrows are turned over for promote aeration and homogenization of the mass, in addition to being conducive to uniform temperature distribution throughout the material. (UNIDO, 2000).

An experimental study in Colombia was conducted of composting of de-hairing waste (Cuervo, N. 2008). The selected composting process was aerobic, in piles, with manual mixing up. Five piles were using dried grass and sawdust as bulking agents, and three types of inoculums: mud from wastewater municipal treatment plant (WWTP), commercially available microorganisms (EM®EMRO) and a culture media prepared with excreta of poultry, cattle manure, material from the nucleus of a pile in mesophilic stage and molasses according indicate Sztern, D. and Pravia, M. (1999). Best results were obtained for compost pile built from hair, sawdust and mud from WWTP. The final compost thus obtained had high nitrogen and organic material content, was a stable product, with a high agronomic value and an adequate degree of maturity. The study concluded that composting is a technically and environmentally feasible technique for reusing de-hairing wastes.

Barrena, R. et al. (2006) obtained good results when co-composted with raw sludge from a municipal wastewater treatment plant at hydrolysed hair: raw sludge weight ratios 1:1, 1:2 and, 1:4 in lab scale and pilot plant scale composters. In all cases, a more stable product was achieved at the end of the process. Temperature evolution curves show a typical behavior of this process, i.e. a rapid increase to temperatures above 60 °C at the beginning of the process, followed by a temperature decrease that was related to the amount of hair in the composting mixture, temperature increased rapidly to the thermophilic stage (over 45 °C) reaching values over 70 °C by second day. Temperatures were kept around this value for several days and then slowly decreased to reach around 40 °C by day 20.

With regard to composting from defleshing grease, Íñiguez, G. et al. (2006) identified in the thermophilic stage achieved maximum temperatures of 56 °C and 65 °C. In the field study, compost treatment was similar to conventional fertilization treatment. The compost was evaluated in a field study determining the yield and quality as well as the incidence of *Rhizoctonia Solani* in potatoes, disease severity caused by *R. Solani,* and quantity and quality of potatoes were also similar ($p < 0.05$) after compost treatment. The high phytotoxicity and worms death could be more related to the high compost sodium concentrations than to compost maturity. The composting process showed to be a good alternative for treating the flesh materials and improved wastewater management. The obtained final product with its high ash and sodium content should be utilized taking into account the recommendations of an agronomist.

Kumar AG (2009) evaluated isolated species of lactic acid bacteria with respect to their efficiency and antibacterial property in the fermentation of limed and delimed tannery fleshings. The experiment resulted in a fermented mass with antioxidant properties, which indicates its potential for an effective bioconversion of fleshings. The one that presented the best antimicrobial spectrum and efficiency of fermentation was the bacteriocin produced by Enterococcus faecium, which turned out to be antagonistic to various human pathogens, including Salmonella, Listeria, Aeromonas and Staphylococcus.

5.1.2 Process drivers

As in any biological process, the factors affecting composting are of several types: environmental conditions, type of waste to be treated and composting technique. Permanent monitoring and control of these factors is of the utmost importance (BCMAF, 1996; Pace, M. et al., 1995):

- **Temperature**. Optimal range is 35-55 °C for effective elimination of pathogen agents, parasites and weed seeds. Higher temperatures mean that helpful microorganisms can die or cannot act because of being in a spore state.
- **Moisture**. Ideal range is 40-60 %. Should larger amounts of moisture be present, water could block every pore in the pile, and the process becomes an anaerobic one, resulting in organic material rotting. The process becomes too slow in the opposite case, because it reduces the activity of micro-organisms. Moisture contents will depend on the type of components chosen: fibrous materials are allowed to have moisture up to 75-85 %, while fresh vegetable material must be in the range 50-60%.
- **pH**. Microorganisms react differently to it: fungi can resist a pH range of 5 to 8, and bacteria a narrower one (6-7.5).
- **Oxygen**. Composting is an aerobic process. Oxygen concentration will depend on factors like material type, texture, moisture, tossing frequency and the availability of forced ventilation.
- **C/N balance**. Carbon and nitrogen are main constituents of organic matter. The adequate quality of any compost depends on a well-balanced C/N ratio. That will vary depending on the components of the compost pile, but a theoretically accepted value is a C/N ratio range of 25-35. Higher values will decrease the biological activity. A very low C/N ratio does not affect the composting process and excess nitrogen transforms into ammonia. Wastes having different C/N ratios must be efficiently mixed in order to ensure well-balanced compost. Organic materials with high C/N ratio are straw, dry hay, leaves, branches, sawdust (UNIDO, 2000). Low C/N ratios are found in young vegetables, animal feces and slaughterhouse residues.
- **Microbial population**. In composting process a wide range of bacteria, fungi and actinomycetes populations are responsible for the completion of the aerobic decomposition of organic matter.

Variables to be controlled in process monitoring are:

- Temperature. A daily measurement, with a portable bimetallic thermometer.
- Moisture. Qualitative evaluation. Water is sprayed as needed.
- pH. Samples measured at the laboratory.
- Physicochemical and microbiological parameters

5.2 Product quality standards

In commercial fertilizers or conditioners like compost, the quality requirements are established by Resolution 150/2003 (ICA, 2003), with the objective of guiding the commercialization and the adequate use and handling of fertilizers and conditioners; also to establish procedures that are in harmony with international standards, for registering and controlling these products from the technical and legal standpoints.

Resolution 150/2003 establishes in article 41 a guaranteed composition according to the labeling approved by ICA, based on Colombian Technical Norm 5167/2004 (ICONTEC, 2004). This resolution regulates the requirements to be met and the tests to be conducted on organic products used as fertilizers or soil conditioners.

A statement must be made regarding the origin of used raw materials, and the transforming processes. The quality standards to be analyzed and guaranteed (on wet basis) by organic fertilizers are shown in Table 5.

Table 3. Parameters to be analyzed and guaranteed for compost as a commercial product

PARAMETER	Organic	Organic-mineral
Volatiles [ϵ]	%	%
Ash[ϵ]	Max 60 %	Max 60 %
Maximum moisture content[ϵ]	Animal 25 % Vegetable 35 % Mix (% of predominant)	15 %
Total oxidizable organic carbon	Min 15 %	>5 % < 15 %
Total Nitrogen	> 1 %	**Report if > 2 % Expressed as: organic N, N-NH_4^{-1}, N-NO_3^-
Total (P_2O_5)	Report if > 1 %	**Report if > 2 %
Soluble potassium (K_2O)	Report if > 1 %	**Report if > 2 %
Calcium (CaO), Magnesium (MgO)	NA	**Report if > 2 %
Minor elements contents	NA	%
C/N Ratio	Result	NA
Cationic Exchange Capability C.E.C.	Min 30 cmol+ Kg^{-1} (meq/100g)	Min 30 cmol+ Kg^{-1} (meq/100g)
Electrical Conductivity	NA	Report
pH	4 a 9	4 a 9
Density	Max 0,6 g/cm^3	g/cm^3
Arsenic -As	Max 41 mg/Kg (ppm)	Max 41 mg/Kg (ppm)
Cadmium -Cd	Max 39 mg/Kg (ppm)	Max 39 mg/Kg (ppm)
Chrome -Cr	Max 1200 mg/Kg (ppm)	Max 1200 mg/Kg (ppm)
Mercury -Hg	Max 17 mg/Kg (ppm)	Max 17 mg/Kg (ppm)
Nickel -Ni	Max 420 mg/Kg (ppm)	Max 420 mg/Kg (ppm)
Lead -Pb	Max 300 mg/Kg (ppm)	Max 300 mg/Kg (ppm)
Acid insoluble residue	NA	Max 50 % of ash
Sodium -Na	NA	Report
Salmonella	Non-detectable in 25 g of final product	Non-detectable in 25 g of final product
Enterobacteria, total	< 1000 CFU/g	< 1000 CFU/g
Nematodes, Protozoo, Enterobacteria	Exempt	Exempt
Microbial load. Content of beneficial microorganisms	Report	Report
Plastics (>2 mm)***	< 0.2 % ms	< 0.2 % dm
Metal (>2 mm) ***	<0.2 % dm	<0.2 % dm
Rubber (>2 mm) ***	<0.2% dm	<0.2 % dm
Glass (>2 mm) ***	<0.02% dm	<0.02 % dm
Stones (>5 mm) ***	<2% dm	<2 % dm
Grease	Max 5% for agricultural use	Max 5% for agricultural use

[ϵ] These parameters must add to 100

* Heavy metals: Only if a blend has been used with waste water treatment plant residues

** Sum of reported elements must be greater than 10%

*** Percentage in dry matter

NA: Not Applicable

Fertilizers typically provide, in varying proportions:

- The three primary macronutrients: nitrogen (N), phosphorus (P), and potassium (K).
- The three secondary macronutrients: calcium (Ca), sulfur (S), magnesium (Mg).
- And the micronutrients (trace minerals) (Purves, D. and Mackenzie, J., 1973): boron (B), manganese (Mn), iron (Fe), zinc (Zn), and copper (Cu).

5.3 Materials and methods

To perform this demonstrative process, was taken into account the results of previous researches on composting, either used tanning, human hair or other wastes.

5.3.1 Materials and facilities

As tannery wastes have been related to strong alkaline conditions, some types of inoculums are to be added to these wastes in order to activate the biological transformation. Also, bulking agents will help to improve the C/N ratio and aeration.

For this demonstrative process, tanneries belonging to the micro-tanners' association ACURTIR, were invited to select from their waste products an amount of 300 to 500 kg of hair, fleshing or leather shavings, generated from the dehairing, defleshing and trimming operations, respectively. Those wastes were to be immediately packed in polypropylene sacks, in order to prevent contamination with some other waste and, after a dehydration period of ten days, transported to the pilot plant and separately stored.

In the pilot process, three types of wastes were used, after being dehydrated and packed: hair, fleshing and chrome shavings contaminated with sawdust.

The physical and chemical characteristics of the tested raw materials used for making the piles are shown in Table 4.

Table 4. Physical and chemical characteristics of the tested raw materials

Parameter	Units	CHROME SHAVINGS	HAIR	FLESHING
pH	-	4,7	9,6	12,4
Moisture	%	19	22	69
Total N-Kjeldahl	(% dry matter)	67361	30898	23979
Cadmium	mg/kg	0,03	0,01	0,03
Chrome	mg/kg	55	0,06	0,7
Lead	mg/kg	0,05	0,05	0,05
Silver	mg/kg	0,04	0,04	0,04
Arsenic	mg/kg	0,003	0,003	0,003
Selenium	mg/kg	0,003	0,003	0,003
Mercury	mg/kg	0,003	0,003	0,003
Barium	mg/kg	0,05	1,09	6
Immobility of Daphnia magna	% at 100% water accommodated fraction (WAF)	0	0	0
Cell density reduction 72h	%	8	0	19

Parameter	Units	CHROME SHAVINGS	HAIR	FLESHING
Growth rate	1/d	1,5	1,56	1,45
Growth inhibition 72h	%	0	0	2
Total Organic Carbon	% w/w	20,23	38	4,59

The bulking agent is a combination of wood sawdust and zeolite. Zeolites are aluminosilicate minerals; with a highly porous structure that allows large ions and water to freely move inside, promoting and the exchange ion hydration and dehydration, and reducing the odor of ammonia produced as final product for protein decomposition (Haug, 1993). In this experiment two natural zeolites were utilized, one called "fine" with a granulometry of 0.5 mm and another “coarse” with grain size between 1 and 3 mm.

As inoculums commercial microorganisms were chosen for this assay. Two different brands: EMRO® and SDC®EM+ were chosen in order to establish if any difference in performance was apparent during the pilot test. The quantity to be applied varies as per supplier recommendations and is dependent on the Effective Microorganisms (EM) activation system and its dilution, as well as supplier’s experience. Water was provided from rain or from a public utility supply.

Effective Microorganisms (EM) are a combination of several beneficial microorganisms from natural sources: phototropic bacteria, lactic acid bacteria and yeasts, mainly used as food additives. When in contact with organic matter, EM secretes vitamins, organic acids, minerals and antioxidants. Antioxidants' effects promote organic matter decomposition and increase the humus content. It also eliminates annoying odors. (BIOEM, 2010)

The materials and the quantity of the piles were determined keeping in mind the number of residues to be studied. On the basis of the hypothesis that tannery residues required an acceleration of their biodegradation with the application of inoculums and also an improvement of process conditions such as the generation of odors, humidity and the agronomic quality of the final product with the application of zeolite.

Three piles were formed as the target of the process, which allowed the evaluation of the biodegradability of the residues by themselves without the addition of inoculums and zeolites.

The pilot process started on July 15th and finished on November 12th, 2010. Piles were built with the characteristics shown in Table 5. Material to be composted (hair, fleshing and chrome shavings), is mixed with sawdust in equal proportions (50/50).

Table 5. Pile characteristics

Pile	Type of Solid Waste	Waste (Kg)	Sawdust (Kg)	Ratio	Zeolite				Inoculum (cc)	
				W:S	Fine (Kg)	%	Coarse (Kg)	%	EMRO	SCD EM+
1	Chrome shavings	200	200	1:1	4	1,00	12	3,00	0	1500
2	Chrome shavings	200	200	1:1	4	1,00	12	3,00	1000	0
3	Chrome shavings	200	200	1:1	0	0,00	0	0,00	0	0
4	Hair	200	200	1:1	4	1,00	16	4,00	1000	0
5	Hair	170	170	1:1	4	1,18	12	3,53	0	1000

Pile	Type of Solid Waste	Waste (Kg)	Sawdust (Kg)	Ratio	Zeolite				Inoculum (cc)	
				W:S	Fine (Kg)	%	Coarse (Kg)	%	EMRO	SCD EM+
6	Hair	170	170	1:1	4	1,18	12	3,53	1000	0
7	Hair	40	40	1:1	0	0,00	0	0,00	0	0
8	Fleshing	200	200	1:1	4	1,00	12	3,00	1000	0
9	Fleshing	200	200	1:1	4	1,00	12	3,00	0	1500
10	Hair:Fleshing (1:1)	80	80	1:1	2	1,25	6	3,75	0	1000
11	Fleshing	50	50	1:1	0	0,00	0	0,00	0	0
12	Hair:Fleshing (1:1)	80	80	1:1	2	1,25	6	3,75	1000	0

5.3.2 Pilot Plant Operational Procedures

Open composting was chosen, building piles of triangular cross sections, laid directly on the floor. The materials to be composted are mixed in the pile without compression, in order to retain air inside. Mixing is needed for the pile to be homogeneously processed. The tossing frequency depends on the material, moisture content and required process rate. It is established by monitoring pile temperature and detecting any foul smell coming from the pile.

A shed was set up for the process, taking up an area of 100 square meters, with a cement floor and chutes were placed around it in order to lead lixiviates towards a tank in case these are generated.

Control equipment: Thermocouple; clean plastic bags for laboratory sample taking.

Pile preparation procedure (Figure 1):

1. Weigh the amount of each type of zeolite indicated for the pile, dividing the coarse fraction in two equal parts.
2. Weigh the indicated amount of composting material in four (4) equal parts.
3. Prepare indicated amount of EM solution: 1 part EM for 4 parts of water.
4. Spread half the weighed amount of coarse zeolite on the assigned area of clean floor.
5. Spread one part of composting material, to spray it with ¼ of prepared EM solution; to repeat this for a second time of composting material and to spread a third part of composting material alone over a zeolite layer.
6. Spread last amount of coarse zeolite and to spray it with ¼ of prepared EM solution on top of last layer of composting material (step 5).
7. Spread the last amount of composting material, to spread one layer of fine zeolite and to spray it with the leftover of EM solution on top of coarse zeolite layer.

Figure 1. Pile preparation photos

(a) First layer: coarse zeolite

(b) First layer of composting material

(c) Spraying a microorganisms' solution

(d) Final layer: fine zeolite

The follow-up and control of the demonstration process conducted in the following manner:

The temperature must be controlled (maximum 60 to 70°C). The pile must be turned over each time the temperature reaches 70°C or at least once per week. It is necessary to spray a new dose of EM-EMRO solution at weeks 3 and 6 and of SCD EM+ at week 3.

At the **start** materials were analytically identified and classified according to the following parameters: Mixture of each residue with sawdust: pH, Moisture, Organic matter, Total N-Kjeldahl, Total fecal Coliforms, E coli, Specific conductivity.

During the composting process, the following analyses were performed: Material in composting process in each pile: pH, Moisture content and Cationic Exchange Capability (CEC)

At the **end** the composted materials were analytically identified and classified according to the following parameters:

Compost: pH, Electrical conductivity Saturated extract, Moisture, Cationic Exchange capability (CEC), Total Nitrogen, Total Potassium, Total Calcium, Total phosphorus, Total sulphur, Sodium, Total Oxidizable Organic Carbon, Total Chrome, Hexavalent chromium, Grease content, percentage of seed germination.

Samples with the best characteristics are subjected to the following tests: Organic matter, ammonia Nitrogen, soluble Phosphorus and the Magnesium, Sodium, Iron, Copper, Manganese, Zinc, and Boron. Counting of characteristic microorganisms in the compost: azotobacter, actinomycetes -type bacteria, nitrogen fixers and phosphates dissolvers. Counting of pathogen microorganisms: total and fecal coliforms and Salmonella sp.

Even though during the pilot process leachate have not been generated.

5.4 Analysis of Results

The evolution of the composting pilot, the results and the measurements carried out are described in this section. The characteristics of the compost with respect to the requirements of Colombian regulations are evaluated.

5.4.1 Characteristics of the mix residue-wood sawdust

On the starting date, samples were taken for analysis of the blank piles. The results are shown in Table 6.

Table 6. Blank piles results

Parameter	Units	Pile 3 (chrome shavings)	Pile 7 (hair)	Pile 11 (fleshing)
pH	-	4,0	8,7	7,6
Moisture	%	5	8	11
Dry matter = 100 - % moisture	%	95	98	89
Organic matter	(% dry matter)	20	24	29
Total N-Kjeldahl	(% dry matter)	12	5	16
Total fecal Coliforms	CFU/100ml*	$2,9 \times 10^{4}$	$9,9 \times 10^{7}$	$1,8 \times 10^{8}$
E coli	CFU/100ml	Negative	$1,5 \times 10^{3}$	$8,5 \times 10^{2}$
Specific conductivity	µS/cm @25 °C	8700	2840	7810

* Colony forming units per 100 ml (cfu/100ml)

The low pH of pile 3 composed of the mix of chrome shavings-wood sawdust is explained as due to the fact that the residue is generated from tanned leather. The tanning is carried out with chromium sulfate in an acid medium with a pH that should be between 3.8 and 4.2.

While the residues of Piles 7 (hair-wood sawdust) and 11 (fleshing-wood sawdust) have a basic pH as they come from the skin in dehaired pelt, this dehairing is carried out in a basic medium utilizing sodium sulfide and lime, which give solutions of pH over 12. (UNIDO, 2000)

The content of organic matter between 20% and 29% indicates that the materials have an organic component that can be stabilized for composting.

5.4.2 Temperature profiles

The temperature in the piles was taken at three points within each pile: in two extreme ends and at the center. The measurement was undertaken daily for the first 8 weeks and afterwards at weeks 10, 13, and 18. In Appendix B the temperature values are presented for each pile during the period pointed out.

Piles behavior depend on its composition, in the case of piles that included chrome shavings remained at ambient temperature during pilot testing as shown in Figure 2, and without any trace of decomposition (Figure 3). This was not an unexpected result, as the chromium-based tanning process stabilizes the proteins-collagen in raw hide indefinitely. This implies that in order to decompose the leather, it would be necessary to first remove the chrome, breaking the chemical bonds formed by the carboxylic collagen group and trivalent chrome, the technique utilized is enzymatic alkaline hydrolysis (Nintzel, A. et al, 1995; INTI and CIATEC, 1996; Hrncirík, J. 2005).

Figure 2. Evolution of the Temperature in Chrome Shavings' piles

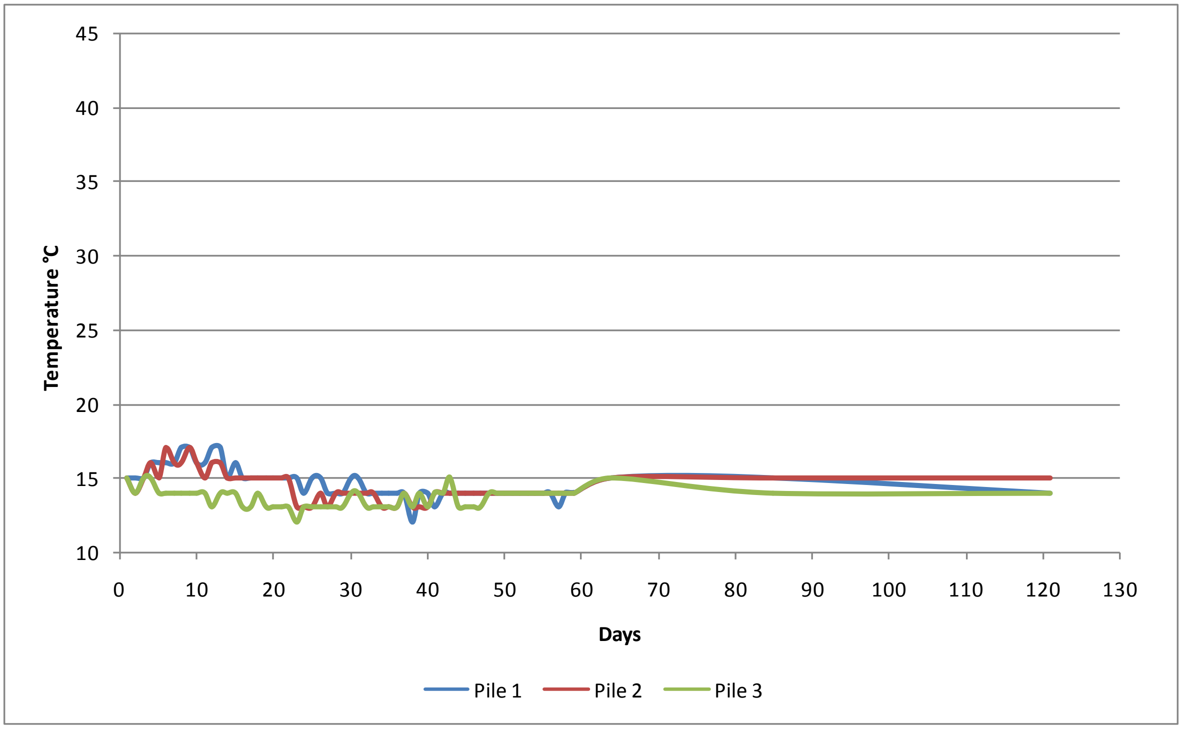


Figure 3. Piles containing chrome shavings

(a) Pile during demonstration process

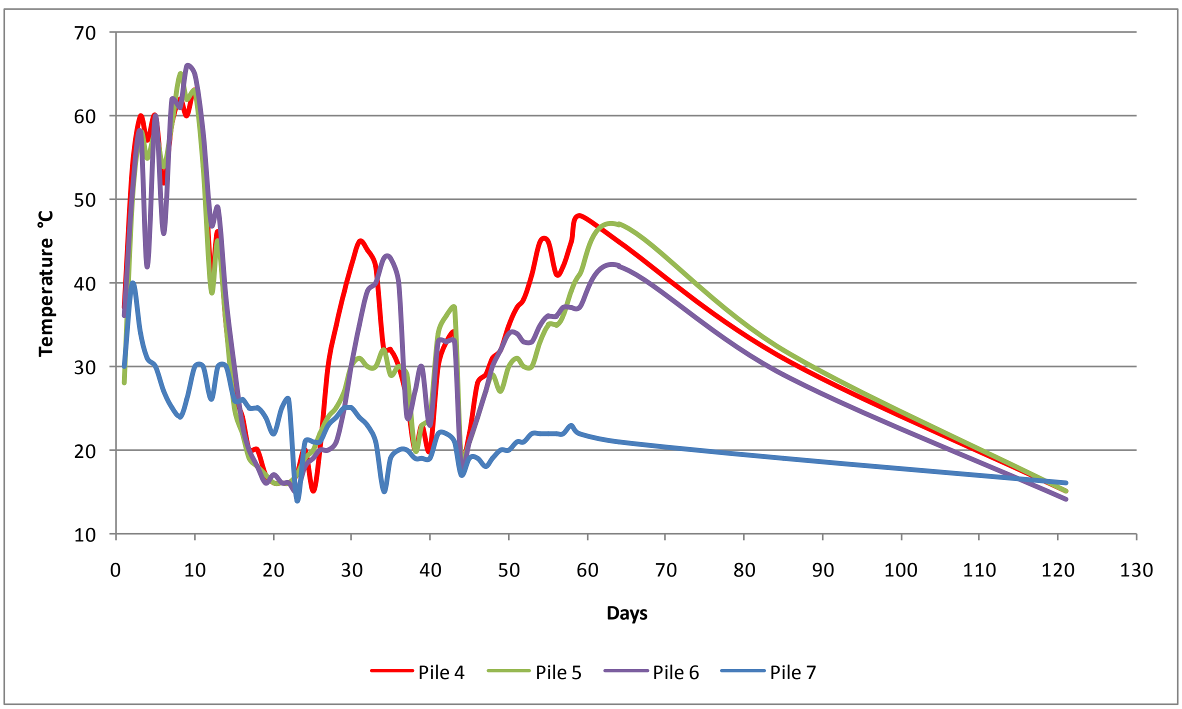
(b) Temperature by week 10

While in composted piles for hair, fleshings or the mix of both residues the temperature varied for the period evaluated, during the experiment variations were observed of temperatures between 12 and 70 °C. In these piles it was found that the temperature of the sides was lower than the temperature at the center of the pile, with differences of between 2 and 8 °C. This is due to the fact that the sides of the pile are exposed to ambient temperature and to the wind. For this study, temperature readings from the center of the piles were analyzed.

In general the piles increased their temperature by the second or third week up to 65°C, identifying the termophilic stage. Subsequently, temperature decreased gradually down to 40°C presenting the cooling stage until the thirteen week. After this week the maturing stage began with a temperature of 15°C. Specifically, piles formed by fleshing, hair or their combination have been composting, increasing their temperature by the second or third week up to 65 °C. By week four, piles were observed to be very dry and their temperature dropped to 30 °C, remaining in the same state for two more weeks, as water was not available in the shed.

Figure 4 shows the evolution of the temperature for hair piles. As can be observed the initial temperature of the process was between 28 and 37 °C, as the residue was collected two weeks before the start of the project and naturally began is degradation process. In the first two weeks, except for pile 7, all the other piles reached temperatures of over 40 °C reaching 66 °C. At weeks 3 and 6 the temperature decreased due to the fact that hydration was not performed. At weeks 5 and 7 hydration was carried out of the piles and the temperature increased again. From week 7 on the piles continued to be hydrated, nevertheless, at week 13 a decrease in temperature was observed, and at week 18 the temperature decreased to ambient temperature.

Figure 4. Evolution of the Temperature in Hair piles

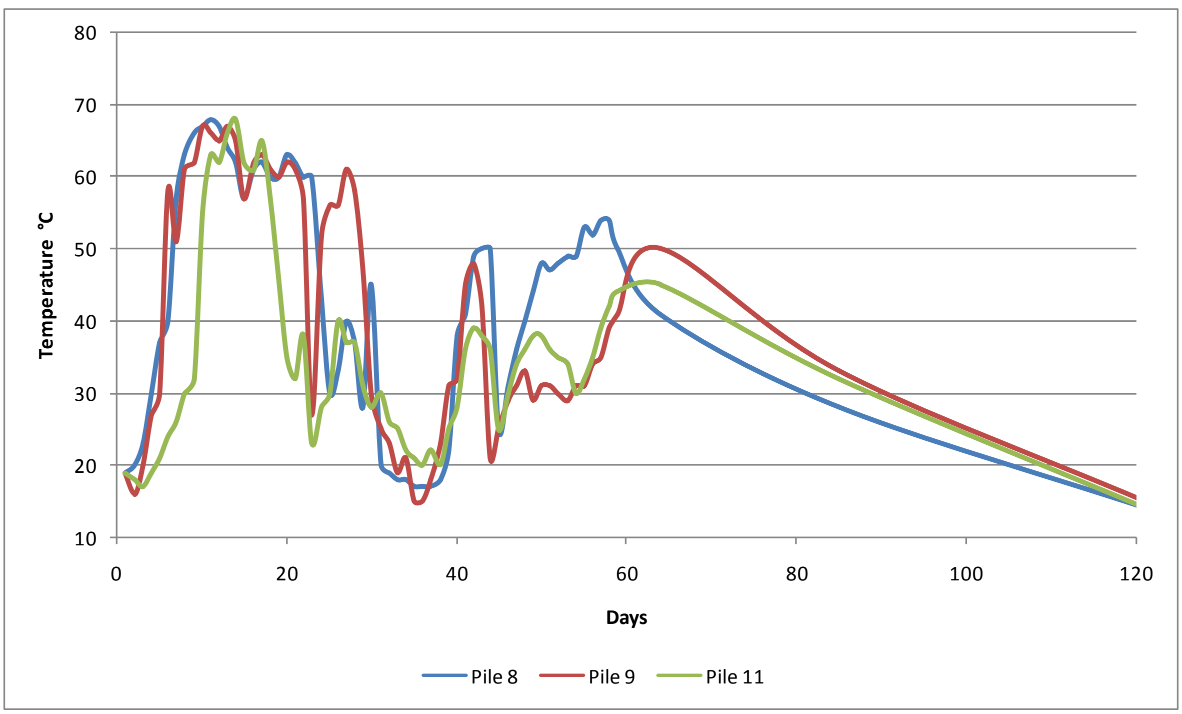


According to that reported by Cuervo, N. (2008), during the composting of partially hydrated hair rapid increases of temperature were evidenced, constituting the first evidence of activation of the composting process, the mesophilic stage which entails the processes that are developed from

ambient temperature up to 40 °C lasted six days. The termophilic stage began reaching temperature peaks greater than 50 °C towards day 20. After this termophilic stage that lasted nearly 70 days, the piles start to lose heat and their temperatures decrease to reach approximately ambient temperature. This stage is known as the cooling stage, its duration varies taking into account that the nutrients have been exhausted and mesophilic microorganisms that develop utilize the more biodegradable resistant materials as nutrients (Sztern, D. and Pravia, M., 1999). At this stage primarily mesophilic bacteria and fungus colonize the compost, more recalcitrant compounds are attacked such as cellulose and lignin, condensation and polymerization reactions occur and the organic matter is humificated (Martínez, G., 2004). At approximately five months, the temperature of the piles decreased to ambient temperature. During the cooling and maturation phase the bacterial diversity increased, including also other Gram-positive and Gram-negative bacteria.

Figure 5 shows the evolution of the temperature for piles of fleshings. As can be observed the initial temperature of the process was 19 °C. During the first week the temperature increases gradually to under 40 °C, in this way identifying the mesophilic stage. In the second week the piles reached temperatures greater than 40 °C reaching 66 °C. At weeks 4 and 6 the temperature decreased due to the fact that no hydration was carried out. At weeks 5 and 7 hydration was carried out and the temperature again increased. From week 7 on the piles continued to be hydrated, nevertheless at week 13 the temperature decreased to ambient temperature.

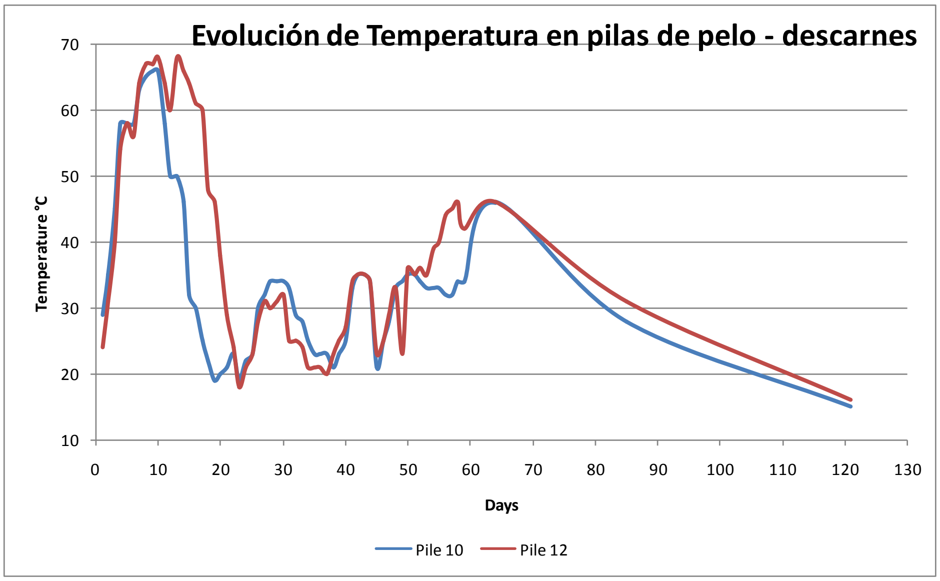
Figure 5. Evolution of the Temperature in fleshings piles



A similar temperature behavior was reported in the fleshings compost study undertaken by Ravindran, B. and Sekaran, G. (2010), where at the initial phase the temperature was 31 °C, after the 14th day it reached 45°C and subsequently increased to 59 °C on day 28, and it continued this way during 2-3 days in the fertilizer mix.

Figure 6 shows the evolution of the temperature for the piles of a mix of hair and fleshings. As can be observed the initial temperature of the process lay between 24 and 29 °C, as the hair had naturally began its degradation process. In the first two weeks, pile 10 reached temperatures greater than 40 °C reaching 66 °C, while pile 12 maintained stable temperatures during three weeks. In the following weeks the temperature decreased due to the fact that no hydration was performed. At week 8 the temperature again increased. At week 13 a decrease of temperature was observed and at week 18 the temperature decreased to ambient temperature.

Figure 6. Evolution of the Temperature in piles of a mix of hair – fleshings



5.4.3 Moisture content

In the fourth week, the moisture content was established as the piles were observed to be highly dehydrated and with a low temperature. At the seventh and thirteenth week, moisture content was determined for all piles. Results are shown in Table 7. From week 4 to week 7 a low hydration of the piles was carried out, and because of this their humidity content did not increase over 40%, reason for which the quantity of water provided was increased, achieving better humidity contents.

Table 7. Moisture content (%)

Pile	4 week	7 week	13 week
4	-	38	50
5	-	34	53
6	31	39	57
7	-	36	62
8	-	12	42
9	20	39	55
10	-	40	58
11	25	37	63
12	-	40	54

By week 9, excess water was added and the piles started to show compaction at their surface, originating in a fungus; by week 10 the fungus reached a thickness of 15 cm, except piles 6 and 7 which had no traces of the fungus. See Figure 7.

Figure 7. Fungus in the piles

(a) Pile 4. Fungus | (b) Pile 8. Fungus | (c) Pile 11. Fungus

Starting at week 9 a whitish micellar tissue appeared towards the inside of the piles, at week 10 pines sprouted, which grew to form a Eumycetes composed of mycelium, volva and striata textured foot. During the experiment no fungus sprotuted from the pile nor pileus developed, and for this reason it could not be classified.

5.4.4 pH and Cationic Exchange Capability

At the eighth and thirteenth week the pH and Cationic Exchange Capability (CEC) were determined. The results in Table 8 showed that the pH reduced mildly, complying with Product quality standards.

The CEC increased considerably, indicating that there was oxidation of the organic matter producing humification through an increase in the humic acids, the humus acts as a deposit of cations; and as the humification process proceeds CEC increases.

Increase in available cations in compost are related to the greater amounts of plant tissues that provide a larger surface area for cation exchange, as was reported by Savala, C. et al. (2003).

Nevertheless, only piles 5, 8 and 12 met Product quality standards.

Table 8. Analytical results of the piles at seventh week

Pile	pH		CEC (meq/100 g)	
	8 week	13 week	8 week	13 week
4	8,1	8,01	0,102	27,12
5	8,2	7,92	0,095	33,15
6	8,2	7,9	0,092	25,81
7	8,2	7,6	0,083	24,58
8	8	7,41	0,094	60,2
9	8,1	7,47	0,082	16,74
10	7,9	7,44	0,08	25,03
11	8,1	7,63	0,084	25,84
12	8	7,28	0,069	43,61

5.4.5 Initial compost identification and classification

The results of the identification and classification of the compost is shown in Table 9, where it can be observed that the samples with better compost characteristics are 4, 5, 7 ,8 and 10.

Table 9. Results at the end of the process

Parameter	Units	4	5	6	7	8	9	10	11	12
Electrical conductivity	dS/m	11,4	11,28	11,05	9,85	7,31	6,86	10,11	12,08	12,28
Total Nitrogen, N	% w/w	1,09	1,05	0,82	1,27	0,79	0,14	0,92	0,45	0,7
Total Phosphorus, P	% w/w	0,03	0,03	0,02	0,02	0,08	0,03	0,03	0,03	0,02
Total Potassium, K	% w/w	0,06	0,044	0,047	0,03	0,052	0,14	0,04	0,041	0,056
Total Sulphur, S	% w/w	0,25	0,27	0,19	0,24	0,1	0,06	0,16	0,07	0,17
Total Calcium, Ca	% w/w	1,87	1,87	1,37	1,75	2,48	1,6	1,91	1,43	1,62
Sodium, Na	% w/w	0,55	0,5	0,43	0,46	0,62	0,39	0,11	0,46	0,53
Total Oxidizable Organic Carbon	% w/w	17,18	12,65	13,31	14,55	18,88	16,51	16,09	13,99	14,52
Ratio C/N	-	15,76	12,05	16,23	11,46	23,90	117,93	17,49	31,09	20,74
Grease content	% w/w	0,51	0,55	0,54	0,03	0,28	0,25	0,07	0,70	0,15

Taking into consideration the values established by Colombian regulations with regard to the total nitrogen content, only piles 4, 5 and 7 complied with the requirement, while the content of Total Oxidizable Organic Carbon is adequate in piles 4, 8, 9 and 10.

In the hair piles the relation C/N is between 11.46 and 16.23, which are high values when compared with those obtained by Cuervo, N (2008) which varies between 3.28 and 3.6

According to the outcomes described by Cuervo, N (2008) and Avendaño, (2003) in order to provide the needed nutrients for growth and multiplication of microorganisms, and to provide the energy organisms consume, 20 to 30 parts of carbon are needed for one of nitrogen. A greater relation may make the process slower and a lesser one runs the risk that the nitrogen may be lost as ammonia (NH_3). Out of the 9 piles studied, only piles 7, 11 and 12 have a C/N relation within this level.

Similar to that reported by Xiao, Y. et al. (2009), in this demo process due to stable similar values of Total Oxidizable Organic Carbon and the low values of Total Nitrogen with small differences in the nine piles, the C/N relation is similar for all piles, except pile 9 due to its low nitrogen content.

After 49 days of composting period, TOC was decreased from 55.6% to 27.9%. This means that TOC was reduced by 49.83% and that this loss of organic carbon as CO2 was through microbial respiration in bacterial composting process. TKN in the compost was increased from 0.85% to 1.99%, probably because of mineralization of proteinaceous organic matter (Table 6). According to Viel et al. (1987), losses in organic carbon might be responsible for nitrogen addition. During the composting of organic matter most likely the microbial utilization of readily decomposable components within the organic matter, such as sugars, starch, lipids, pectin, amino acids and nucleic acids occurs.

Ravindran, B. and Sekaran, G. (2010) report that regarding the fleshings compost, that after 49 days of the process, the carbon was reduced from 55.6% to 27.9% and nitrogen increased from 0.85% to 1.99%, maybe as a result of the mineralization of the proteinic organic matter.

With respect to calcium and sodium content, values were expected to be greater than 2% considering the utilization of lime and sodium sulfide in the dehairing and liming operations. The greater values reported were found in pile 8, the calcium value was 2.48% and sodium was 0.62%.

In the study by Cuervo, N. (2008) calcium concentrations were found between 1 and 2% and between 1 and 2.5% for sodium, attributing to this content the inhibition in seed growth.

The results reported by Íñiguez, G. et al. (2006) show high sodium concentrations (1.08 y 1.21%) in the compost from fleshings, reason for which the use of the product for garden or golf grass fields is recommended given the constant watering practiced in this activity; although in field tests no problem occurred from using this compost in the potato crop.

On the other hand, KAZMAN, Z et al (1983) noted that low levels of exchangeable sodium can occasion the compaction of the soil, affecting the water an air reserves in the soil.

When there is calcium deficiency a necrosis will be observed of young leaves' apices and tips aside from some type of deformation of the leaves, generally hooked downwards with the borders hunched towards the inferior face or adopt a jagged appearance, and frequently chlorosis in the new growth. Sodium is vital for the regeneration of the phosphoenopiruvic acid, as its deficiency generates necrosis and chlorosis, specially for plants like corn, sugar cane, and many other tropical grasses, cactus, agaves, orchids and bromelias (Taiz, L. and Zeiger, E., 2006)

5.4.6 Chrome

Given that the residues utilized in the composting process come from the tannery industry it was necessary to quantify and report its chrome content that can become a limitation for the use of the compost obtained. Table 10 shows that none of the piles exceeds the limits established by regulations.

Table 10. Results at the end of the process

Parameter	Units	4	5	6	7	8	9	10	11	12
Total Chrome, Cr	mg/kg	20,78	32,24	38,85	72,94	31,46	36,54	35,12	22,23	20,81
Hexavalent Chrome	mg/kg	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1

5.4.7 Percentage of seed germination

In the determination of the percentage of seed germination were used lettuce seeds of the Great Lakes Batavia variety, which were sowed in different combinations of compost and peat. Table 11 shows that the piles with the greater percentages of seed survival are: 7, 8, 9, 10 y 11.

Table 11. Percentages of seed germination

%w/w sample	Unit	4	5	6	7	8	9	10	11	12
0	%	83,75	83,75	83,75	85	97,22	85	85	83,75	83,75
20	%	76,25	66,25	70,83	82,5	95,69	80,63	81,88	75	70,63
40	%	73,75	65,63	50,83	76,88	92,44	80	71,87	73,33	51,88
60	%	52,5	52,5	47,5	75,62	91,41	74,38	70	71,67	45
80	%	25	24,11	25	66,25	88,71	71,25	66,25	70,83	25,63

The compost produced from hair in piles 4 and 7 present low percentages of seed germination, among which pile 7 (blank) achieved better results with values superior to 66%; similar results are reported by Cuervo, N. (2008) in which the combinations with the greater quantity of composted material did not have germination and only in 2 of the 4 piles seed survival percentages present were over 50%.

Ravindran, B. and Sekaran, G. (2010) point out that the composted organic fertilizer (derived from fleshings) did not have an inhibitory effect on the seed germination of tomato, green gram, bottle pumpkin and cucumber crops. Likewise, it can be observed in the compost produced in piles 8 to 11, in which fleshings were utilized, that survival percentages are greater than 66%; the contrary occurred in pile 12 where it can be observed that by increasing compost concentration, the survival or germination percentage is reduced, indicating that the material would have phytotoxic effects.

Sánchez M. (2002) reports that the values for the germination index following the third week of the process suggest that the material would not have phytotoxic effects, even if the matter was still decomposing. Additionally, it points out that the high percentage of seed germination, from the first phases of the composting process could represent a limitation of this test as an indication of stability in the case of green residues.

According to the germination indexes (71 – 97%), the best results were obtained for two compost piles. Those piles were composed by fleshing and wood sawdust. Better organic matter decomposition and less bad odors were identified at the piles with inoculums and zeolite compared with the control piles.

After observing the laboratory results the five best composts produced were selected in order to carry out a second group of physicochemical and microbiological analysis. The compost selected was that produced in piles 7, 8, 9, 10, and 11. Their results met the regulatory demands or were very close to those requirements, and in addition presented the best seed survival indexes.

5.4.8 Microbiological analysis

Table 12 presents the results of the microbiological analysis of the beneficial and pathogenic microorganisms content.

Table 12. Content of beneficial and pathogenic microorganisms

Parameter	Units	7	8	9	10	11
Beneficial Microorganisms						
Azospirillium sp.	CFU/g	1.30×10^{10}	1.90×10^{07}	1.60×10^{08}	6.40×10^{08}	7.50×10^{09}
Azotobacter sp.	CFU/g	4.70×10^{08}	2.20×10^{07}	6.30×10^{08}	3.40×10^{08}	3.40×10^{09}
Actinomycetes	CFU/g	<10	<10	<10	<10	<10
Phosphates dissolvers	CFU/g	4.00×10^{07}	1.50×10^{07}	5.50×10^{08}	3.50×10^{08}	7.50×10^{08}
Pathogenic Microorganisms						
Salmonella sp	CFU/g	Absent	Absent	Absent	Absent	Absent
Fecal Coliforms	CFU/g	<10	<10	<10	<10	<10
Total Coliforms	CFU/g	1.00×10^{03}	<10	4.50×10^{04}	1.50×10^{03}	1.70×10^{07}

Regarding beneficial microorganisms it can be observed that composts produced have a high content of nitrogen and phosphate fixers, while that of actynomicets were very low.

With regard to Salmonella sp., the result is satisfactory. Piles 9 and 11 of fleshings compost and pile 10 of hair-fleshings compost present total coliforms in quantities over that established by the norm (see Table 3), only piles 7 and 8 comply.

The results obtained by Cuervo, N (2008) for hair compost were adequate, with a high presence of beneficial microorganisms, and as for pathogens there was no presence of Salmonella sp., for any of the piles and there was a significant reduction of fecal coliforms. For this reason, according to the criteria of the U.S. EPA, the compost complies with Class A requirements with respect to the reduction of pathogens.

In the bacterial composting experiment of animal fleshing carried out by Ravindran, B. and Sekaran, G. (2010), pathogenic microorganisms such as fecal coliforms, *Salmonella spp*., and *Shigella spp* were eliminated in the compost mix after 35 days.

5.4.9 Secondary elements

Table 13 presents the results of the analysis of the content of secondary elements, in general the 5 piles of compost produced contain microelements, since all of them have a nutritional value for crops, and nevertheless, none has a concentration level greater than 2%.

Table 13. Content of beneficial and pathogenic microorganisms

Parameter	Units	7	8	9	10	11
Magnesium, Mg	% w/w	0.05	0.07	0.08	0.07	0.05
Assimilable phosphorus, P	% w/w	0.02	0.02	0.02	0.02	0.02
Ammonia Nitrogen, N-NH4	% w/w	<0.01	<0.01	<0.01	<0.01	<0.01
Boron, B	% w/w	0.0006	0.0001	0.001	0.0002	0.0019
Copper, Cu	% w/w	0.0009	0.0007	0.0007	0.0007	0.0005
Manganese, Mn	% w/w	0.0035	0.0047	0.0041	0.0038	0.0028
Iron, Fe	% w/w	0.13	0.16	0.15	0.12	0.06
Zinc, Zn	% w/w	0.004	0.0021	0.0016	0.0028	0.0018
Total Oxidizable Organic Carbon	% w/w	15.35	19.58	15.47	15.86	18.97

5.4.10 Product classification

The compost obtained in this pilot process, given its composition may be classified as a "natural organic soil conditioner" according to the NTC norm 1927 (ICONTEC, 2001).

These cannot be classified as fertilizers of primary elements given that they do not contain more than 1% of N, P or/and K; nor as fertilizers on the basis of secondary elements since their Ca, Mg and S contents are less than 2%; neither as fertilizers on the basis of micronutrients given that their content of secondary elements or trace elements is less than 2%.

Because of their pH greater than 7 and the calcium content, it could be useful in acid soils with a pH less than 5.5, but its application should be undertaken under the guidance of an expert.

5.5 Knowledge transfer

Seven tanners made part of the pilot team, and they were trained to transfer knowledge to tanners interested in the composting process.

Additionally, parallel experiments were carried out in three tanneries, using residues generated by these tanneries, with some variations in the composition of their piles. See Figure 8.

Figure 8. Composting practices in tanneries

Tannery La Pradera: Hair and fleshings with wood sawdust.	
Tannery Curtinorte: Hair with wood sawdust and rice husks	
Tannery Villasol: Wool, hair, fleshings with cow manure and wood sawdust	

In the first two tanneries an evolution of the composting similar to that of the pilot process was observed.

In the tannery where the wool degradation was performed, a greater slowness was observed in the composting, as reported by Zheljazkov, V. (2005) due to the difficult degradation of the wool. The results from this study suggest that wool and hair waste may be excellent soil amendments and nutrient sources for high value crops for both greenhouse and field production systems.

6 BASIC DESIGN OF THE COLLECTION AND RECOVERY PLANT

The valorization of the residues requires a place equipped with the adequate installations for the processing, collection and commercialization of the materials.

The layout of the collection and recovery plant should contain specific areas for each activity. To determine the size of the installations 200 Tm of composting residues are taken as the basis of the calculation.

Table 14 presents the areas that make up the plant, and their size in square meters that in total reach 2014m^2 of buildings. These buildings would be constructed in a land plot acquired by ACURTIR, which has an area of 1.2 hectares (12,000 m^2).

Table 14. Areas that make up the collection and recovery plant (m^2)

AREAS	***m^2***
Shed for composting (cemented floor, iron columns and Zinc ceiling)	1500
Wastewater treatment plant (PTAR, by its Spanish initials)	10
Storehouse to store supplies (cemented floor, brick walls on sight and Zinc ceiling)	90
Storehouse for storing the compost produced	180
Storehouse for storing salt used for sale	30
Storehouse for storing commercial supplies utilized in the tanning process	100
Administrative offices, bathrooms, locker rooms, and cafeteria	24
Meeting hall: auditorium, showroom	80

The installations would be located towards the center of the land plot, leaving an area of equal size foreseeing the need to extend the installations in case ACURTIR decides to handle a greater quantity of residues or to implement other recovery alternatives. Figure 9 shows the basic layout of the areas in the land plot.

Figure 9. Layout of the land plot

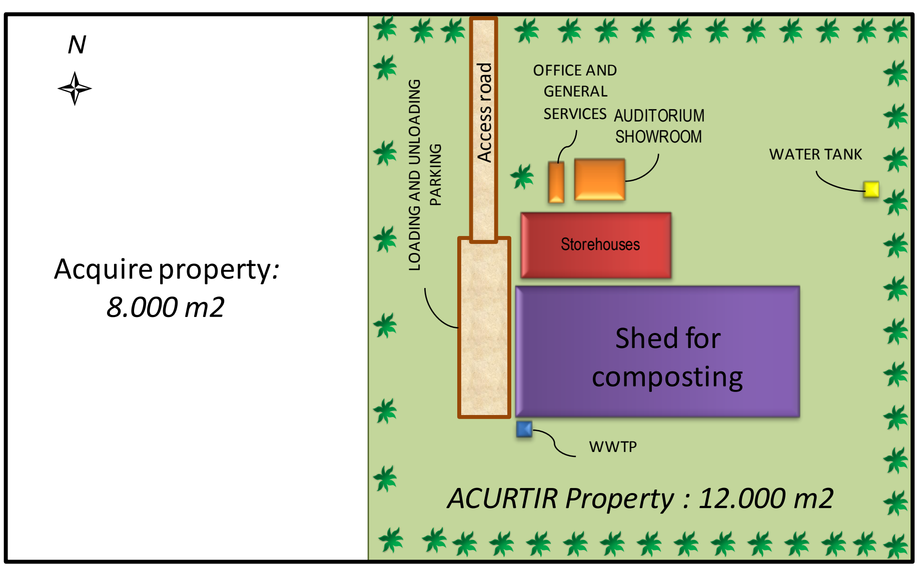


Table 15 presents a list of items that make up the initial investment budget and the monthly operation budget.

Table 15. Investment and operational budget

ITEM	VALUE $ Col	Value Euro*	Value Dollar*
INVESTMENT BUDGET	$ 619,912,000	$ 247,496	$ 323,714
INFRASTRUCTURE, FURNITURE AND EQUIPMENT	$ 598,912,000	$ 239,112	$ 312,748
BUILDING CONSTRUCTION	$ 415,600.000	$ 165,926	$ 217,023
PUBLIC SERVICES INFRASTRUCTURE CONSTRUCTION	$ 65,000.000	$ 25,951	$ 33,943
FURNITURE AND EQUIPMENT	$ 33,312,000	$ 13,300	$ 17,395
VEHICLE - TRUCK 350	$ 85,000,000	$ 33,936	$ 44,386
LEGALIZATION EXPENSES	$ 7,000,000	$ 2,795	$ 3,655
COMPANY REGISTRATION	$ 2,000,000	$ 798	$ 1,044
PRODUCT REGISTRATION – ICA	$ 5,000,000	$ 1,996	$ 2,611
EXPENSES IN CONSTRUCTION WORK DESIGN AND MANAGEMENT	$ 14,000,000	$ 5,589	$ 7,311
MONTHLY OPERATIONAL BUDGET	$ 31,841,250	$ 12,712	$ 16,627
OPERATIVE PERSONNEL * MONTH	$ 3,911,250	$ 1,562	$ 2,042
ADMINISTRATIVE PERSONNEL * MONTH	$ 3,050,000	$ 1,218	$ 1,593
PUBLIC SERVICES AND MAINTENANCE	$ 3,400,000	$ 1,357	$ 1,775
MATERIALS AND INPUTS * MONTH	$ 21,480,000	$ 8,576	$ 11,217

* Representative market exchange rate as of December 27, 2010. 1 EUR= 2,504.73 COP and 1 USD = 1,915.0 COP

7 ENVIRONMENTAL ASPECTS

7.1 Environmental evaluation

Decree 1220/05 (MAVDT, 2005) establishes that a project, construction work or activity such as a residue management plant, includes the planning, siting, installation, construction, assembly, operation, maintenance, dismantling, abandonment and/or termination of all actions, uses of the space, activities and infrastructure related and associated with its implementation. It also establishes, in Article 9 that the Regional Autonomous Corporations will grant or deny the environmental license for construction projects and the operation of installations whose purpose is the storage, treatment, recovery and/or final disposal of residues or hazardous waste.

The Environmental Evaluation that is developed in this section is based on the diffuse or multiple criteria methodology, which facilitates the identification of activities with the most impact and the environmental factors most affected, allowing the use of numeric and linguistic information of the alternatives without the need to undertake any transposition of linguistic variables to a numeric scale (Garcia, L. 2004). See Appendix C.

From the analysis of the activities, the environmental factors and the identification of their cause-effect relationships, potential environmental impacts are deduced. The project's impact will be the difference between the modified future environment, as would result after the implementation of the project, and the future environmental situation as it would have normally evolved without such intervention.

This project as a sum of alternatives, none of the activates related with the construction stage represent a significant contribution to the total environmental impact of the project, as all are of relatively irrelevant importance and the movement of soils and the cleaning and occupation of the soil are only of a moderate nature.

The stage of the operation of the plant has activities that individually produce an impact of relative irrelevant importance, with the exception of the occupation of the terrain and the presence of buildings, the reception and storage of residues which are environmentally negative, and the control of operational conditions which are positive.

In the surroundings, impacts on the environmental factors have an irrelevant importance as none of these have a significant contribution to the environmental imbalance. The impacts are homogeneous in importance, nevertheless in the physical medium the factors of greater importance are the generation of gases, and the emission of particles. In the biotic medium the impacts are irrelevant and in the socio-cultural medium the greatest effects are on the landscape.

According to results, the alternatives are environmentally viable as their affectation on the surrounding environment in general are classified as irrelevant to moderate, but it is very important to implement the needed preventive and corrective measures to mitigate their effects. In relation to the place where the project is located, it does not represent en environmental threat by any means, given that it has to do with a project the purpose of which is to resolve a problematic in industrial residues management.

7.2 Green seal or Ecoseal

At present in Colombia there does not exist a specific green seal for compost. Nevertheless, Resolution1555/05 (MAVDT, 2005) regulates the use of the Colombian Environmental Seal, which specifies the guidelines to follow in order to obtain accreditation.

Accreditation can also be obtained applying the series of norms ISO 14020:2000 Environmental labels and declarations -- General principles. For this labeling an Environmental Management System (SGMA, by its Spanish initials) should also be implemented such as EMAS or ISO 14001 that normally require the environmental evaluation of the products, demand environmental requirements to the providers; the purchase of products eco labeled is a say to comply with these requirements in the supply chain.

From the industrial perspective, the user of a Seal may obtain the following potential benefits:

- improve competitiveness, position in the market and the image of the organization,
- orient commercial strategy towards specialized and high growth markets,
- achieve more efficient processes, less use of materials and power and a reduction of residues to dispose of,
- achieve or surpass client expectations,
- improve clients' loyalty,
- attract investors and sources of financing, particularly those with an environmental conscience,
- reduce the responsibility due to a decrease in environmental impacts,
- improve relationships with regulatory entities,
- facilitate the identification and processing of legal requirements.

8 ECONOMIC FEASIBILITY

This section compares the possibility of valorization and commercialization of residues with regard to the possibility of disposing of the residue through external companies.

<u>Revenues for the recovery of residues</u>

The tanneries associated to ACURTIR, will in association undertake the valorization of the residues generated and the commercialization of the resulting products. It is assumed that in the composting plant, approximately 200 tons of generated residues will be received monthly, which will be combined with 30% of a structuring material like wood sawdust. It is calculated that from this volume 160 Tm will be produced monthly. The production of compost would start following the ninth week of the process and from then on it will continue to be produced continuously.

Supplementary to this, another business alternative is the sale of 28 Tm of impure salt. See Table 16.

Table 16. Monthly revenues for the sale of Compost produced monthly

ITEM	*VALUE $ COL*	Value Euro*	Value Dollar*
SALE OF COMPOST	$ 28,800,000	$ 11,498	$ 15,039
SALE OF IMPURE SALT	$ 3,360,000	$ 1,341	$ 1,755
TOTAL SALES	$ 32,160,000	$ 12,840	$ 16,794

* Representative market exchange rate as of December 27, 2010. 1 EUR= 2,504.73 COP and 1 USD = 1,915.0 COP

If the operational expenses are compared with the sales revenues, it can be observed that the balance is practically zero, since revenues just manage to cover expenses. In consequence the initial investment would be difficult to recover starting from the revenues.

According to information provided by the Departamento de Impuestos y Aduanas Nacionales (Department of National Taxation and Customs) - DIAN, the compost is exempt from taxes, according to Article 476 of the Estatuto tributario (Tax Statute) numeral 12.

<u>Expenditures for the disposal of residues through external companies</u>

If the 30 tanneries decide to dispose of their residues through external companies they will have to pay for this disposal service, the transport and laboratory analysis required by the external company. They will not receive any income. See Table 17.

Table 17. Monthly costs of the disposal of the residues

Disposal alternative	200 Tm/month Hair/Fleshings	28 Tm/month Salt	Total $ COL	Value Euro*	Value Dollar*
Disposal in safety cells	$ 367,200,000	$ 50,400,000	$ 417,600,000	$ 166,724	$ 218,068
Disposal by means of incineration	$ 510,000,000	$ 70,000,000	$ 580,000,000	$ 231,561	$ 302,872
Bioremediation	$ 142,800.000	N/A	$ 142,800.000	$ 57,012	$ 74,569
Transport from Villapinzón to	$ 30,600,000	$ 4,200,000	$ 30,600,000	$ 12,217	$ 15,979

Bogotá					
Analysis of residues	$ 2,500,000	$ 2,500,000	$ 5,000,000	$ 1,996	$ 2,611

* Representative market exchange rate as of December 27, 2010. 1 EUR= 2,504.73 COP and 1 USD = 1,915.0 COP

Comparison of recovery and disposal costs

The comparison is realized with a horizon of one year for monthly installments. The recovery costs are considered only as the initial investment and operational expenses, without taking into account sales revenues. With respect to disposal costs, the most economic alternatives were selected. bioremediation for the hair and safety cells for salt, adding the value of the transportation and the laboratory analysis.

In Table 18 it can be observed that the cost of **disposal** of the residues is very high, the **valorization and commercialization** alternative being more attractive, which in addition represents an ACURTIR asset. Analyzing the values it is concluded that with the value of 3 months of disposal the total investment value of the composting plant would be paid for and there would be budget left over to operate the plant for 3 months.

Table 18. Comparison of the costs of recovery and disposal

ALTERNATIVE	Monthly value	A year's value $ COL	Value Euro*	Value Dollar*
Valorization and commercialization	$ 81,750,583	$ 981,007,000	$ 391,661	$ 512,275
Disposal	$ 228,800,000	$ 2,745,600,000	$ 1,096.164	$ 1,433,734

* Representative market exchange rate as of December 27, 2010. 1 EUR= 2,504.73 COP and 1 USD = 1,915.0 COP

9 CONCLUSIONS AND RECOMMENDATIONS

PILOT PROJECT WASTES COMPOSTING

The piles increased their temperature by the second or third week up to 65°C, identifying the termophilic stage. Subsequently, temperature decreased gradually down to 40°C presenting the cooling stage until the fifteen week. After this week the maturing stage began with a temperature of 15°C. According to the percentage of seed germination (71 – 97%), the best results were obtained for two compost piles. Those piles were composed by fleshing and wood sawdust. Better organic matter decomposition and less bad odors were identified at the piles with inoculums and zeolite compared with the control piles.

The final compost obtained was a stable product, with an adequate agronomic value and degree of maturity. By the resulting composition of the physicochemical and microbiological analysis the product was classified as a soil conditioner.

Composting of hair, fleshing or a combination of both wastes has demonstrated being a feasible technical option in Villapinzón that positively impacts the environment.

It is advisable to undertake further tests with piles of greater volume in order to standardize the composition characteristics of the compost, such that the content of the primary and trace elements may be established with greater precision, and therefore the classification of the product as a fertilizer or soil conditioner.

Technically it is possible to enrich the product with the needed nutrients in order to classify it and commercialize it as an organic fertilizer.

COLLECTION AND RECOVERY PLANT

It is more costly to dispose of the residues than to undertake their recovery.

The construction of the residue collection and recovery plant is technically, environmentally and economically feasible.

For the construction of the infrastructure it is essential to count with civil and architectural designs that take into account an adequate layout in the plant according to the sequence of operations of the productive process.

10 GLOSSARY

Thermophile: [Organism] that requires higher-than-ambient temperature for its normal development. [Microorganism] whose living optimal temperature is over 45 °C.

Mesophile microorganism: characterized by having an optimal growing temperature between 20 ºC and 45 ºC. Its minimum temperature is in the range 15 ºC to 20 ºC and the maximum around 45 ºC. Pathogens are part of this group.

Natural organic soil conditioner: Product of animal and/or vegetable origin, stabilized and handled in an environmentally clean manner, which is applied to the soil to improve its physical and biological properties. Its content of primary nutrients (NKP) is less than 2 %w/w of the finished product in a dry base.

Organic fertilizer: organic matter of animal and/or vegetable origin, stabilized and handled in an environmentally clean manner, both in its processing as well as in the transportation. It is added to the soil fundamentally for plant nutrition.

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Appendix A. Selection of recovery alternatives

Appendix B. Temperature values for each pile during the period pointed out

Appendix C. Environmental evaluation

APPENDIX A. SELECTION OF RECOVERY ALTERNATIVES

For the selection of recovery alternatives, the residues of major environmental impact or of high cost are identified qualitatively and quantitatively, and also the opportunities for recovery that provide an economic benefit, either by not having to pay environmental fines, by the reduction of costs in the management of residues, or by generating revenues from exploited residues.

Table 1 presents the quantities of residues generated per tonnage of raw skin and by group of tanneries according to information provided by ACURTIR with respect to association members who currently have a productive process in operation. It is calculated that a plant will service approximately 30 active tanneries, with an average monthly production of skins of 700 units for a total of 21000 skins the equivalent of 468 tons of raw or green skin.

Table 1. Type and quantity of residues generated

Type of residue	*Quantity generated (Kg/Tm raw skin)*	*Average weight (Kg/Tm raw skin)*	*Monthly average weight for the group of active tanneries (Tm)*
Impure Salt	14 to 28	21	9.8
Trimmings of raw skin and grease	1 to 8	4.5	2.1
Hair	120 to 185	152.5	71.4
Grease and post dehairing fleshing trimmings	200 to 385	292.5	137.0
Flesh split pelt (*Sub-product*)	150 to 485	317	148.5
Leather trimmings	2.5	2.5	1.2
Chrome Shavings	20 to 285	152.5	71.4
Trimmings of finished leather	15 to 28	21.5	10.1
Emery dust	4 to 7	5.5	2.6
Contaminated supply containers and packages, and accessories	1 to 4	2.5	1.2
Sludge	11 to 20	15.5	7.3

Source: IDEA-UNC Technical Team

Table 2 presents the current management, the CP requirements prior to the generation of the residue and the valorization alternatives of each residue

Table 2. Valorization alternatives and prior requirements

Type of residue	*Current management*	*CP requirements prior to implementing the alternative*	*Available recovery alternatives*
Impure salt	Reused in salting fresh skin or for the production of brick. It is disposed of as a domestic residue.	Recovery of salt adhered to the skin (utilized for preservation): Using a mesh drum, sweeping or beating the salted skins. Weigh the salt, pack it and accumulate it in a dry place.	Recover and reuse prior treatment in salting of skins or in pickling. Sale to metallurgic, brick, and chemical industries
Raw skin and grease trimmings	They are dehairing and sold for the production of gelatin.	Perform a pre-defleshing prior to dehairing so that in these trimmings there is no presence of pollutants like sulfur or lime whose presence would make difficult the treatment and would	Sale to glue, gelatin, food, animal toys, grease, cosmetic, hydrolyzed collagen industries.

Type of residue	Current management	CP requirements prior to implementing the alternative	Available recovery alternatives
		increase costs. *	
Hair	Non-technical composting within the company. Delivery to third parties for composting.	Perform dehairing with hair recovery.*	Production of fertilizer. External: animal food, flowerpots, hydrolyzed keratin, activated carbon, biofuel.
Grease and fleshing trimmings post dehairing	Deposited in the soil in agricultural production zones. Large chunks are sold as low grade flesh for the production of gelatin.	Eliminate leather borders that are useless for the final product. *	Same as for trimmings of raw skin but eliminating sulfur and lime. Fertilizer production.
Flesh split pelt	Production of suede or food or toys for animals. It is considered a sub-product.	Carry out splitting keeping in mind the quality of the product.	Production of suede. Sale to the food or toys for animals, collagen, detergents, hydrolyzed, and human food industries.
Leather trimmings in blue	Final disposal. Some tanneries incinerate them generating air pollution.	Prior to tanning, eliminate the borders of the "flower" that are useless for the final product. *	Same as with shavings
Shavings	Some businesses sell it for the production of reconstituted leather. The shavings combined with wood sawdust are deposited in the soil. It is generated in businesses that do not have a drainer and is deposited in agricultural soil.	Perform the operation of shaving without contaminating the chrome shavings with wood sawdust, utilize a drainer machine. *	Sale to reconstituted leather, brick, gelatin industries. Eliminating the chrome: paper, cosmetic, sun blocker, fertilizer, collagen, animal food, adhesives. Composting
Finished leather trimmings	Final disposal. Some tanneries incinerate them generating air pollution.	Minimize its quantity, making trimmings on the border of the skin, taking care not to tear the commercial product.	Production of handicrafts.
Emery dust	It is accumulated in the plant, there is no control system for particulate material.	Perform the grinding in a dry, enclosed place with cemented floor to facilitate its collection	Sale to reconstituted leather industry. Generation of power by controlled incineration. Composting
Contaminated supply containers, packages and accessories	These are reused or are delivered to be disposed of in the municipal dump mixed with domestic residues. Some businesses return the containers to their providers.	Totally empty the containers, without wasting supplies; locate a specific place for its temporary storage. Destine a recipient to deposit contaminated accessories (paper, bags, cloths, etc.)	Reuse as containers for the same supplies. Program of return of containers for reuse or recycling.
Sludge	Dried and combined with ordinary residues for its disposal.	Periodically collect when undertaking maintenance of installations or equipment. *	Sale to power generation industry

** Residues with a high content of humidity (Skin, leather, grease trimmings, hair, shavings, emery dust) should be packed separately in sackcloths, stored and the water allowed to be drained in an adequate setting with a liquid collection system and sent to PTAR, weighed after draining.*

1.1 PRELIMINARY EVALUATION OF ALTERNATIVES

Of the alternatives presented in the previous section, a preliminary evaluation will be undertaken that allows discarding those alternatives that:

- demand a high investment that is not available,
- or that cannot be implemented because either they modify the production process flow in place in the region,
- or because they require the application of very complex technologies currently unavailable in this case

Therefore these will not be subsequently studied in-depth.

On the other hand, priority options are determined, as due to limitations in resources not all will be able to be implemented. The alternatives with greater priority will be evaluated in a feasibility study. The designation of priorities is a mixture of "common sense", economic, technical and environmental issues.

In order to evaluate the alternatives and estimate their degree of importance was taken into account: the economic capacity of the tanneries in the region, the technologies with which these currently operate, it was estimated the cultural level and the aspirations held of these businesses. Likewise, the expected environmental improvement derived from theoretical data was evaluated, which should be proven with tests carried out in the same zone, under real conditions.

Figure 1 shows the different evaluation criteria and the score assigned in order to carry out the qualitative assessment.

The prioritization of the alternatives was undertaken through an arithmetic sum of each one of the criteria. It is important to point out that the alternative that does not count with the commitment of any business owner for its implementation will be discarded. An alternative will be considered to be a priority when the total sum is greater than 45 points. Options with scores between 20 and 44 points should be evaluated experimentally in order to establish their feasibility.
Table 3 shows the results of the assessment of the associative recovery alternatives of solid residues, from which it is concluded that the alternatives subject of the feasibility study are:

1. Donation or sale of the salt used, to the metallurgic, brick or chemical industries
2. Production of fertilizer by hair composting
3. Production of fertilizer by composting of fleshings

And the recommended alternatives for experimental analysis and subsequent feasibility study are:

1. Recovery and reuse of impure salt in salting or pickling
2. Extraction of greases from pre-defleshing
3. Production of flowerpots and other articles of a biodegradable character derived from hair
4. Production of activated carbon or biofuels from hair
5. Production of proteins derived from fleshings of the defleshing post dehairing
6. Donation or sale of leather trimmings and shavings uncontaminated with other materials
7. Organic fertilizer of vegetable tanning residues
8. Production of power through the incineration of dry residues, being able to recover chrome oxide from the ashes.
9. Leather plates for leather goods articles and in shoe insoles produced from leather shavings and trimmings
10. Production of gelatin from raw skin trimmings, fleshings, hair and tanned leather.
11. Composting of PTAR sludge

Figure 1. Criteria of pre-selection of alternatives of solid residues management to be implemented associatively

CRITERIA	VALUE	DESCRIPTION OF GRADER
Commitment Association-Association members	0	No commitment in implementing requirements of residue adjustment
	7	Adjusts the residues but is not interested in participating in the financing of valorization alternative
	15	Willing to adapt to the requirements and to co-finance the alternatives
Approximate cos tof Alternative	0	Over 100 minimum salary wages or No reliable information available
	5	Cost between 40 and 100 minimum salary wages
	10	Between 20 and 40 minimum salary wages
	15	Less than 20 minimum salary wages
Access to Technology	0	No currently available existence in the country, nor any known representatives
	5	It is available but requires very specialized technology and highly qualified personnel for its management
	15	The knowhow exists or training can be easily accessed, employs a simple technology
Environmental Cost-benefits	0	Does not allow compliance with regulatory limits
	5	Other residues difficult to manage are generated elevating costs
	10	No residues are generated that are difficult to manage and the cost-benefit relationship is zero
	15	No residues are generated that are difficult to manage and generates profits for the association

Source: IDEA-UNC Technical Team

Table 3. Assessment of associative recovery alternative of solid Residues

No.	Residue	ALTERNATIVE	DESCRIPTION	COMMITMENT	COST	ACCESS TO TECHNOLOG	ENVIRONMENTAL BENEFIT	TOTAL
1	Impure Salt	Recover and reuse the impure salt in salting or pickling	Salting of skins: With prior thermal treatment In pickling: with prior dissolution and filtration treatment Unknown technology	7	10	5	5	27
3		Donation or Sale to metallurgic, brick, chemical industries	Temporarily store the salt in containers that allow keeping it dry and deliver to industry	7	15	15	10	47
4	Raw skin and grease trimmings (pre-defleshing)	Extraction of grease from pre-defleshing	A technical extraction process should be carried out of grease by heat with a controlled process in an industrial plant with all the respective environmental controls and licenses. Currently, some tanneries are profitably undertaking the recovery of grease, there being no existing experience in protein flour.	4	5	7	7	23
5		Artificial gut for cold meat industry (gut trimmings).	The more spongy part of the trimming is used, which corresponds to the neck and flank. The defleshing trimmings are cleaned of flesh and are placed in lime during various weeks. Afterwards they are washed, acidified with acids that have a liotropic effect, washed again, taken to a determined degree of swelling. In this state they may be disintegrated and homogenized by a mechanical shredder, obtaining a doughy mass that should be manipulated cold. This mass is passed through some nozzles, endeavoring to turn it around to avoid it acquiring a parallel arrangement, rather by intertwining increasing the mechanical resistance of the tube formed. Air is insufflated to maintain the tube form of exiting material. This tube of collagen can be subjected to the action of formaldehyde, which due to its tanning characteristic produces a union of the fibers improving their indeformability. Lastly, it undergoes a drying process until the maximum humidity is of 10 - 15%. Afterwards it can be folded in packages and stored during a period of time, having to again be hydrated when it is going to be utilized.	0	0	7	7	14
6		Sale to other industrial sectors	External production of glues, gelatins, food and toys for animals, grease, cosmetics, Surgical and Pharmaceutical elements. The obtaining of these products from tannery residues requires very complex technologies that are expensive and many times require acquiring the respective patents.	7	15	15	15	52
7		Artificial mane for the upholstery industry and for the manufacture of brushes and brooms (defleshing and gut trimmings)	By an analogous procedure of the artificial gut, and with the same sub-products, an artificial mane may be obtained. Once the amorphous mass is formed it is made to pass through a series of fine circular nozzles where it will exit in the form of a continuous thread. The hardening treatment is performed with chrome salts that improve its resistance to water. The filament that is obtained is applied in upholstery, the manufacture of brushes and brooms. Protein flour and industrial grease (flesh in gut). This alternative, despite presenting as highly promising, above all considering the product obtained, turns out to be more complex and should be automated with the purpose of reducing costs.	0	0	7	7	14

No.	Residue	ALTERNATIVE	DESCRIPTION	COMMITMENT	COST	ACCESS TO TECHNOLOG	ENVIRONMENTAL BENEFIT	TOTAL
8	Hair	Production of fertilizer	Technical composting employing efficient microorganisms.	15	0	15	15	45
9		Production of flowerpots and other articles of a biodegradable nature	Technology unknown	7	5	7	7	26
10		Production of hydrolysate of keratin	Careful process of temperature hydrolysis and controlled pressure with diluted hydrochloric acid during the time necessary to solubilize. The hydrolysate is whitened with activated carbon and then filtrated, obtaining in this manner a brilliant liquid of amber color. Final product of hydrolysate of keratin	0	0	7	7	14
11		Production of activated carbon or biofuels	By enzymatic treatment	7	0	7	7	21
12	Residues of post dehairing defleshing	Production of proteins	Requires the elimination of sulfur and lime	7	0	7	15	29
		Production of fertilizer	Technical composting employing efficient microorganisms.	15	0	15	15	45
13	Residues from tanned leather (trimmings, shavings)	Donation or Sale to other industrial sector	Sale to reconstituted or agglomerate leather, brick, gelatin industries. Eliminating chrome: paper, cosmetics, sun blocker, fertilizers, collagen, animal food, adhesives.	7	0	15	7	29
14		Organic fertilizer from vegetable tanning residues	Where waste is generated from vegetable tanned leather. By the shavings of vegetable and synthetic leather being biodegradable, putting them into a pile will produce their fermentation. This product contains large quantities of organic matter and nitrogen, reason for which it could be utilized as is for fertilizer, but it is preferable to proceed to its grinding and mixture with other products to be able to obtain a fertilizer with the nutritional requirements that plants require.	5	5	15	10	35
15		Additive to ceramic pastes (trimmings of tanned hide).	This option derives from an experimental study that employs trimmings of chrome tanned hide with or without finishing. The additive has been carried out on construction ceramics: gresificated pavements and bricks.	0	0	7	7	14
16		Produce power through the incineration of dry residues, recovering chrome oxide from the ashes.	The composition of dry leather residues has a high percentage of Carbon (45%), which allows considering about its utilization to produce calorific power by incineration. the ashes produced are in the order of 6% of which between 2 and 5 percent belong to chrome oxide and the rest to mineral salts. The calorific potency is of some 18.83 (J7g). In addition, chrome oxide left in the ashes could be useful, and for this reason its recovery could be tried.	7	0	7	7	21
17		Leather plates for upholstery articles and shoe insoles.	Shavings and leather trimmings are utilized. The manufacture is executed in four phases: preparation of the fibrous material, fixing of the binder, formation of the plate and finishing.	7	0	7	15	29
18	Trimmings of raw hide,	Production of gelatin	Gelatin is obtained as colloid hydrophilic type, the technology employed is the conversion of fibrous proteins of the connective collagen tissue, as well as its	15	0	15	10	40

No.	Residue	ALTERNATIVE	DESCRIPTION	COMMITMENT	COST	ACCESS TO TECHNOLOG	ENVIRONMENTAL BENEFIT	TOTAL
	Unsplit pelt grease, hair and tanned leather		final transformation in gelatin. Gelatin has multiple uses such as the manufacture of ink rollers in print shops, in the tanning of skins, India ink, artificial leather, films and photographic paper. Due to the presence of heavy metals its use in food items is restricted. Yield: to produce a Ton of gelatin approximately from 6.5 to 7 tons of residues are required.					
19	Sludge	Composting	Its use is foreseen as an organic fertilizer, previously composted; it can have limitations due to its content of heavy metals	7	10	15	7	39

TEMPERATURE VALUES FOR EACH PILE DURING THE IDENTIFIED PERIOD

PILE	Week	July 15 - Week __1__							July 22 -Week __2__							July 29 - Week __3__							August 5 - Week __4__							August 12 - Week __5__						
	POINT	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Pile 1	Side 1	15	15	13	15	15	15	16	14	15	16	15	15	15	15	16	14	14	14	14	13	13	14	14	14	15	15	13	13	14	14	15	14	14	14	14
	Center	15	15	15	16	16	16	16	17	17	16	16	17	17	15	16	15	15	15	15	15	15	15	15	14	15	15	14	14	14	15	15	14	14	14	14
	Side 2	15	13	14	15	15	15	15	15	16	15	14	15	16	13	14	13	14	14	14	13	13	14	14	13	13	13	14	14	14	14	15	13	13	14	13
Pile 2	Side 1	15	14	14	16	14	15	16	15	16	15	14	15	15	14	14	14	14	14	14	13	13	14	13	13	13	13	12	14	14	14	15	13	14	12	13
	Center	15	14	15	16	15	17	16	16	17	16	15	16	16	15	15	15	15	15	15	15	15	15	13	13	13	14	13	14	14	14	14	14	14	13	13
	Side 2	15	14	14	16	13	16	14	14	14	15	14	14	15	14	14	13	14	13	14	13	13	13	12	12	12	13	13	13	13	13	13	13	13	13	13
Pile 3	Side 1	15	14	12	14	13	18	14	13	14	14	13	14	13	13	14	13	14	13	13	13	13	13	12	12	12	13	13	13	13	14	13	13	13	13	12
	Center	15	14	15	15	14	14	14	14	14	14	14	13	14	14	14	13	13	14	13	13	13	13	12	13	13	13	13	13	13	14	14	13	13	13	13
	Side 2	15	13	12	12	12	12	12	12	13	13	13	14	13	13	14	12	12	13	13	13	13	12	12	12	12	13	13	13	13	13	13	13	13	13	13
Pile 4	Side 1	34	38	31	26	25	31	49	41	39	44	31	58	38	30	24	22	19	18	15	15	15	15	16	16	18	20	23	26	30	32	32	33	33	32	29
	Center	37	54	60	57	60	52	59	62	60	63	57	41	46	35	27	24	20	20	17	16	16	16	17	20	15	20	30	35	39	42	45	44	42	32	32
	Side 2	34	40	35	38	44	45	54	46	47	38	39	33	41	31	25	20	20	18	16	15	15	16	16	18	19	23	26	26	32	35	39	33	33	34	29
Pile 5	Side 1	24	42	42	34	34	35	42	45	40	29	34	55	37	26	22	19	18	18	15	16	15	15	16	16	18	19	21	21	22	24	24	25	25	24	25
	Center	28	50	58	55	58	54	59	65	62	63	54	39	45	35	25	22	19	18	17	16	16	16	17	19	20	22	24	25	27	30	31	30	30	32	29
	Side 2	28	38	35	33	36	33	51	46	36	39	31	51	38	29	25	20	18	18	16	16	15	15	16	17	18	19	20	26	21	21	23	23	25	24	26
Pile 6	Side 1	30	36	39	27	34	31	35	46	50	50	50	57	41	33	26	20	19	17	15	15	15	15	15	17	17	18	19	21	25	26	26	33	32	34	38
	Center	36	51	58	42	60	46	62	61	66	65	58	47	49	38	30	23	20	18	16	17	16	16	15	18	19	20	20	21	25	30	35	39	40	43	43
	Side 2	34	36	31	30	33	42	56	53	48	45	44	26	39	32	26	21	19	17	11	15	15	15	14	16	16	18	16	18	25	23	24	28	30	30	36
Pile 7	Side 1	30	34	30	25	24	28	21	23	23	25	28	30	25	29	24	23	21	21	20	18	20	20	13	20	21	21	21	23	23	26	25	23	22	18	20
	Center	30	40	34	31	30	27	25	24	26	30	30	26	30	30	26	26	25	25	24	22	25	26	14	21	21	21	23	24	25	25	24	23	21	15	19
	Side 2	30	30	23	25	24	22	21	22	24	24	26	26	25	25	24	24	23	22	21	19	21	22	14	20	21	21	24	23	24	25	22	22	20	16	19
Pile 8	Side 1	19	18	19	20	25	29	40	44	63	64	59	60	56	54	63	58	58	55	56	52	51	53	15	38	42	40	45	36	27	36	19	20	18	18	16
	Center	19	20	23	30	37	40	57	63	66	67	68	67	64	62	57	61	62	60	60	63	62	60	60	43	30	33	40	37	28	45	20	19	18	18	17
	Side 2	19	15	19	22	30	27	46	60	64	64	63	61	59	60	62	59	60	52	55	58	54	52	29	45	39	46	53	52	28	40	20	18	16	16	15
Pile 9	Side 1	19	14	17	20	25	52	40	52	62	65	65	65	62	62	64	58	60	59	58	60	69	56	27	40	56	56	61	58	47	30	25	23	19	21	15
	Center	19	16	20	27	30	58	51	61	62	67	66	65	67	65	57	62	63	61	60	62	61	57	27	52	56	56	61	58	47	30	25	23	19	21	15
	Side 2	19	15	16	20	21	62	39	52	60	64	65	61	60	60	36	60	57	55	60	58	51	58	28	33	46	54	50	52	42	30	28	23	20	16	15
Pile 10	Side 1	25	30	31	39	32	44	56	59	52	60	56	50	49	46	32	30	25	25	21	21	21	24	19	21	21	28	28	29	30	30	28	27	26	23	22
	Center	29	35	45	58	58	58	63	65	66	66	58	50	50	46	32	30	25	22	19	20	21	23	19	22	23	30	32	34	34	34	33	29	28	25	23

PILE	Week	July 15 - Week __1__							July 22 -Week __2__							July 29 - Week __3__							August 5 - Week __4__							August 12 - Week __5__						
	POINT	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	Side 2	25	29	36	40	49	52	58	62	58	61	57	48	40	35	27	25	21	19	16	17	20	19	18	19	23	26	31	28	28	30	29	26	24	23	23
Pile 11	Side 1	19	17	15	15	11	21	21	21	25	37	48	58	60	61	60	59	56	56	40	29	23	30	22	20	25	30	31	24	29	24	25	24	22	19	18
	Center	19	18	17	19	21	24	26	30	32	55	63	62	66	68	62	61	65	57	46	35	32	38	23	28	30	40	37	37	31	28	30	26	25	22	21
	Side 2	18	15	14	15	19	19	22	25	26	35	52	56	60	61	64	60	58	58	47	32	25	37	19	22	26	30	35	30	28	29	25	22	24	18	18
Pile 12	Side 1	19	23	25	29	38	54	61	62	62	60	50	58	59	57	55	51	49	34	26	21	22	21	17	20	22	26	29	26	21	22	21	21	21	18	19
	Center	24	31	40	54	58	56	64	67	67	68	64	60	68	66	64	61	60	48	46	38	29	24	18	21	23	28	31	30	31	32	25	25	24	21	21
	Side 2	21	25	27	28	39	54	64	63	61	61	57	57	61	65	55	50	43	35	30	28	25	21	17	18	19	23	25	23	20	21	21	20	22	20	21

PILE	Week	August 19 - Week __6__							August 26 - Week ___7_							September 2 - Week __8__					September 9 - Week __9__			September 16 - Week 10__	October 6 - Week __13__	November 10 - Week __18__
	POINT	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**1**	**2**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**16**	**7**	**12**
Pile 1	Side 1	14	15	12	14	14	14	14	12	14	14	14	14	14	14	14	14	14	14	14	13	14	14	15	14	15
	Center	14	14	12	14	14	13	14	14	14	14	14	14	14	14	14	14	14	14	14	13	14	14	15	15	14
	Side 2	14	15	12	13	13	14	14	15	14	14	14	14	14	14	14	14	14	14	14	13	14	14	15	13	13
Pile 2	Side 1	14	13	13	12	13	14	14	13	14	14	14	14	14	14	14	14	14	14	14	13	14	14	15	15	14
	Center	13	14	13	13	13	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	15	15	15
	Side 2	13	13	13	13	14	14	14	12	13	12	13	13	14	14	14	14	14	14	14	14	14	14	15	15	15
Pile 3	Side 1	13	14	13	14	14	12	14	14	13	13	13	13	14	14	14	14	14	14	14	14	14	14	15	13	13
	Center	13	14	13	14	13	14	14	15	13	13	13	13	14	14	14	14	14	14	14	14	14	14	15	14	14
	Side 2	13	13	13	14	14	14	14	13	13	13	13	13	14	14	14	14	14	14	14	14	14	14	15	14	13
Pile 4	Side 1	29	27	19	20	23	24	30	31	20	23	22	27	29	33	34	34	41	42	38	39	43	45	30	24	14
	Center	30	26	20	23	20	30	33	34	19	22	28	29	31	32	35	41	45	45	41	42	45	48	45	31	15
	Side 2	27	29	20	21	17	25	25	31	20	29	29	31	32	32	34	32	41	41	40	42	44	46	36	26	14
Pile 5	Side 1	26	25	20	22	26	28	30	32	20	22	23	24	27	28	30	27	29	30	30	32	34	36	29	25	13
	Center	30	29	20	23	24	34	36	37	19	21	24	27	29	27	30	30	33	35	35	36	39	41	47	32	15
	Side 2	25	21	20	24	25	30	31	34	19	20	27	25	27	27	30	28	31	32	31	32	35	36	26	22	14
Pile 6	Side 1	35	24	25	23	32	30	29	29	18	20	24	29	27	30	32	29	30	31	31	31	32	33	24	19	13
	Center	40	24	27	30	23	33	33	33	18	21	24	27	30	32	34	33	35	36	36	37	37	37	42	29	14
	Side 2	34	23	23	25	20	27	29	29	18	21	24	24	27	29	30	28	29	32	31	30	30	32	20	20	14
Pile 7	Side 1	20	21	19	19	21	20	22	21	19	19	18	17	20	19	20	21	20	20	20	22	22	22	16	15	14
	Center	20	20	19	19	19	22	22	21	17	19	19	18	19	20	20	22	22	22	22	22	23	22	21	19	16
	Side 2	19	20	19	18	15	19	20	21	16	18	20	16	19	21	20	21	22	23	22	22	22	22	15	17	15
Pile 8	Side 1	18	18	18	20	31	32	40	41	41	25	31	35	35	36	44	45	45	48	51	51	43	45	29	22	14

PILE	Week	August 19 - Week __6__							August 26 - Week ___7_							September 2 - Week __8__					September 9 - Week __9__			September 16 - Week 10__	October 6 - Week __13__	November 10 - Week __18__
	POINT	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**1**	**2**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**16**	**7**	**12**
	Center	17	17	18	22	38	41	49	50	50	25	31	36	40	44	48	49	49	53	52	54	54	50	41	28	14
	Side 2	18	18	18	22	29	38	42	45	45	19	31	34	36	40	42	45	47	43	49	50	57	46	35	26	15
Pile 9	Side 1	15	18	23	29	38	39	39	42	21	24	26	27	28	29	30	25	22	30	31	31	32	31	28	24	14
	Center	15	18	23	31	32	45	48	42	21	25	29	31	33	29	31	29	31	31	34	35	39	41	50	33	15
	Side 2	16	19	23	29	29	37	39	39	21	25	28	28	27	27	28	25	24	25	26	28	30	31	26	23	14
Pile 10	Side 1	22	20	24	21	28	30	32	32	30	23	24	29	31	34	35	31	30	32	30	30	30	30	26	21	15
	Center	23	23	21	23	25	33	35	35	34	21	25	28	33	34	35	33	33	33	32	32	34	34	46	28	15
	Side 2	24	23	20	24	24	28	32	32	32	21	24	27	28	33	36	31	31	33	30	30	31	30	24	19	13
Pile 11	Side 1	20	20	20	24	29	31	35	34	34	24	25	31	30	36	34	31	30	31	31	33	37	40	30	23	15
	Center	20	22	20	25	28	36	39	38	36	25	30	34	36	38	38	34	30	32	35	39	42	44	45	32	14
	Side 2	20	22	21	22	22	32	36	37	32	25	28	30	34	32	35	31	29	30	31	35	38	41	27	25	14
Pile 12	Side 1	20	21	24	28	29	29	34	34	31	22	27	27	32	35	35	31	33	34	40	42	43	45	33	24	15
	Center	21	20	23	25	27	34	35	35	34	23	25	29	33	23	36	35	39	40	44	45	46	42	46	31	16
	Side 2	21	21	22	25	25	38	35	35	30	22	26	28	31	31	33	31	31	33	36	38	40	42	35	27	15

APPENDIX C. ENVIRONMENTAL EVALUATION OF COMPOSTING PLANT

Environmental factors and Project activities

The Environmental Evaluation that is described in this section is based on the diffuse or multiple criteria methodology, which facilitates the identification of the most impacting activities and the environmental factors most affected that allow making use of the numeric and linguistic information of the alternatives without the need to undertake any transposition of linguistic variables to a numeric scale:

- Environmental factors: are a set of variables that allow imparting specific knowledge of the territory, in the immediate environment. The most representative ones are identified taking into account the zone affected by the project. In this inventory the *physical, chemical, biological and perceptual* (landscape) characteristics of the territory, and those *socio-economic and socio-cultural* factors related to human activity, and the interaction of these factors are included. The area of study is defined as the surface limited by a circumference of a radius of 120M (with the Center at the projected installation), a radius of 2 Km is established as that related to emissions in the atmosphere or animal and vegetable species in the area. Instead, for variables like demography, health, or work force the reference is the Municipalities of Villapinzón and Chocontá.

- Project activities: activities inherent to the project that can occasion an environmental impact. These are classified according to the moment of their realization: the preparation phase of the site, construction and installation work, and the phase of operation. This last phase is the longest which together constitute the lifecycle of the project, implying the entrance of materials, supplies and power leading to the outcome of compost production, liquid emissions to be subsequently reused in the process and that will be treated in a wastewater treatment plant as part of the project.

Table 4 describes the environmental factors with their corresponding units of weighted importance (UWI) and the project activities.

Table 4. Identification of environmental factors and project activities

Identification of environmental factors			Identification of project activities	
	PHYSICAL MEDIUM (46 %)	UWI %		CONSTRUCTION STAGE
	Waters (12 %)		A1	Movement of machinery
F1	Availability of water	4	A2	Movement of soil, clearing/removal
F2	Water quality	4	A3	Construction debris
F3	Underground waters	4	A4	Transportation of materials
	Atmosphere (20 %)		A5	Power consumption
F4	Odors (VOC)	4	A6	Fuel consumption
F5	Generation of Gases	4	A7	Water consumption
F6	Emission of particles	4	A8	Drainage works and water storage
F7	Luminic radiation	4	A9	Use of the soil
F8	Noise and vibration	4		OPERATIONAL STAGE
	Soil (14 %)		A10	Occupation of the territory and the presence of buildings
F9	Change of use	3	A11	Storage of rain water
F10	Changes in natural drainage	3	A12	Air renovation in the installations
F11	Infiltration by accidental	4	A13	Reception and storage of residues

	discharges			
F12	Land value	4	A14	Power consumption
	BIOTIC MEDIUM (18 %)		A15	Consumption of process water
	Flora (9 %)		A16	Consumption of water in bathrooms
F13	Changes in the vegetation	3	A17	Leachates
F14	Diversity of species	3	A18	Hydration of the compost
F15	Reduction of natural spaces	3	A19	Water treatment and reuse
	Fauna (9 %)		A20	Operation of machinery and equipment
F16	Increase in noxious fauna	3	A21	Motor vehicles loading and unloading residues
F17	Pathogenic agents	3	A22	Control of operational conditions
F18	Illness-insect vectors	3	A23	Ground transportation of residues
	SOCIO-CULTURAL MEDIUM (36 %)		A24	Residues and refuse to landfill
	Landscape (12 %)		A25	Treatment of fermentable residues
F19	Quality of the landscape	6		
F20	Alterations and visibility	6		
	Health (12 %)			
F21	Public health	6		
F22	Personnel health	6		
	Employment generation (4 %)			
F23	Workforce demand	4		
	Urban development (8 %)			
F24	Management of residues	4		
F25	Investment in public services	4		
	ENVIRONMENT TOTAL	100		

Based on: García, Luis. Aplicación del análisis multicriterio en la evaluación de impactos ambientales (Application of multiple criteria analysis in the evaluation of environmental impacts). Spain, 2004.

Environmental Impacts

The environmental impacts are all favorable or unfavorable alterations produced by an action, program or project to the environment or to some of its components. From the analysis of the activities, the environmental factors and the identification of their cause-effect relationships, the potential environmental impacts are deduced. The project's impact will be the difference between the modified future situation of the environment, as would result after the realization of the project, and the future situation of the environment as it would normally have evolved without such intervention. These relationships are presented in the form of tables and matrixes.

CONSTRUCTION STAGE

During the construction stage the following activities are carried out: movement of machinery, movement of soil and clearing, the production of construction debris, the transportation of materials, power consumption, fuel consumption, water consumption, land occupation, drainage works, and storage of water. These activities will have an impact on environmental factors, as follows:

1. Movement of machinery: generates combustion gases, emission of particles, noise and vibration, which negatively impact the air environmental factor, although on the other hand, positively impacts the socio-economic medium by generating a source of employment.
2. Movement of soil and clearing and cleaning: have a negative impact on the air environmental factor by the emission of particles and the noise and vibration produced on the soil by the change of use and the changes in the natural drainage, on the flora by the changes in vegetation, on the landscape as it affects the quality of the landscape, but positively impacts the socio-economic medium as it requires manpower.
3. Generation of construction debris: produces emission of particles that negatively impact the air factor, and impact the landscape by defacing the natural landscape when they are present in the construction, which requires the immediate management of residues.
4. Transportation of materials: similar to the movement of machinery, it has a negative impact on the air factor by the generation of combustion gases, emission of particles and the noise and vibration it occasions. Its positive side is the generation of jobs, which activates the economy.
5. Power and fuel consumption: in lighting, electrical machinery and the welding of structures, as well as with the internal combustion machinery such as concrete mixers, which have direct and indirect negative impacts on the air quality factor due to the combustion gases produced, and the emission of particles into the environment.
6. Water consumption in the construction site: impacts the water environmental factor mainly due to its availability for other uses.
7. Drainage works and the storage of water: impact the water factor as far as its availability, occasion noises and vibration, and changes in the natural drainage that impact the soil factor.
8. Occupation of the soil: occasions a negative impact on the soil factor due to changes in the natural drainage, to flora because it represents a barrier to the diversity of species, and to the landscape because it changes its visibility and alters the landscape.

STAGE OF OPERATION

At this stage the impacts identified, which affects each factor are primarily due to the Composting Plant and to a lesser degree the storage zones for the commercialization of residues, the factors impacted are:

1. Water: The activities that negatively impact the water environmental factor in its aspect of availability and quality are those related to the consumption in the process and in hygienic services, the hydration of the compost and the discharge of leachates. In so far as underground waters the activities that negatively impact water are the occupation of the land and the presence of buildings and the harnessing of rain water. On the other hand, the activities that positively impact the quality and availability of water are the storage and use of rain water.
2. Air: is negatively impacted by the air renovation in the Piles, the consumption of power, the operation of machinery and equipment.
3. Soil: the activities that negatively impact the soil are the land occupation, the presence of buildings, the storage of rain water, the infiltration of leachates, the hydration of the compost, the treatment and reuse of water. On the other hand, the activity that positively impacts water is the control of operational conditions in order to avoid accidental discharges.
4. Flora and fauna: are impacted by the occupation of the land and the presence of buildings.
5. Landscape: is negatively impacted by the activities in the operational phase by the occupation of the land and the presence of buildings.
6. Health, employment and urban development: are favorably impacted by project activities among others by the air renovation of the Piles, which favor workers' health, the treatment and reutilization of the water or leachates, the good operation of the machinery and equipment, and the control of operational conditions

Evaluation of Impacts

In order to evaluate the importance of the environmental impact, variables are organized in the Matrix of importance. Factors are listed in the first column and the actions in the first file. Impacts are written in the

intersecting cells, these are graded as irrelevant (I), Moderate (M), severe (S), critical (C), positive (+) or negative (-).

Given that the residue commercialization alternatives are very similar, their study will be undertaken jointly. Table 5 shows the matrix of importance of the impacts of these alternatives. The matrix of importance of the composting alternative is presented in Table 6.

Table 5. Matrix of importance of the impacts of commercialization alternatives

ENVIRONMENTAL FACTORS			PROJECT RELATED ACTIONS																								
			CONSTRUCTION STAGE									OPERATIONAL STAGE															
	UIP		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25
Physical Medium	F1	4							M-	M-			M+					S-									
	F2	4																S-	M-		M+						
	F3	4										S-	S-						M-								
	F4	4												M-	M-				I-								
	F5	4	S-			M-	M-	S-															I-				
	F6	4	M-	M-	M-	M-	M-	S-															I-				
	F7	4														I-											
	F8	4	M-	S-		M-									I-								I-				
	F9	3		S-								S-															
	F10	3		M-							M-	S-															
	F11	4								M-									I-					S+			
	F12	4										C-															
Biotic Medium	F13	3		M-								S-															
	F14	3									S-	S-															
	F15	3										M-															
	F16	3										M-			M-									M+		M-	
	F17	3												I-	M-									S+		M+	
	F18	3												I-	M-									M+			
Socio-cultural Medium	F19	6		M-	M-							S-															
	F20	6									S-	S-															
	F21	6												I-	M-						M+			M+			
	F22	6												M+	M-								M-	M+		M+	
	F23	4	I+	I+		M+									I+								I+				
	F24	4			I+																M+					M+	
	F25	4												M+	I-						M+						

Table 6. Matrix of the importance of impacts of the composting alternative

ENVIRONMENTAL FACTORS			PROJECT RELATED ACTIONS																								
			CONSTRUCTION STAGE									OPERATIONAL STAGE															
	UIP		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25
Me	F1	4							M-	M-			M+				S-	S-		M-	M+						

ENVIRONMENTAL FACTORS			PROJECT RELATED ACTIONS																								
			CONSTRUCTION STAGE									OPERATIONAL STAGE															
		UIP	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25
	F2	4															S-	S-	M-	M-	M+						
	F3	4										S-	S-														
	F4	4												M-	M-											M-	S+
	F5	4	S-			M-	M-	S-								S-						S-	M-		M-		
	F6	4	M-	M-	M-	M-	M-	S-						M-	I-	S-							M-		M-		
	F7	4																									
	F8	4	M-	S-		M-									I-							M-	M-		M-		
	F9	3		S-								S-															
	F10	3		M-							M-	S-	S-														
	F11	4																	M-	M-	M-			S+			
	F12	4										C-															
Biotic Medium	F13	3		M-								S-															
	F14	3									S	S-															
	F15	3										M-															
	F16	3										M-			M-									M-		M-	M+
	F17	3												I-	M-									S+	M-	M+	S+
	F18	3													M-									M+	M-	M+	S+
Socio-cultural Medium	F19	6		M-	M-							S-													M-		
	F20	6									S-	S-															
	F21	6												I-	M-						M+			M+	M-		M+
	F22	6												M+	M-								M+	M+		M+	M-
	F23	4	I+	I+		M+																					
	F24	4			I+																M+				M+	M+	S-
	F25	4												M+							M+				M+		

By analyzing the above tables, the actions that have major importance on the surroundings represented by the set of factors shown in Table 7 can be identified, where it can be observed that land occupation and the presence of buildings has a critical impact on the surroundings and the Reception and storage of residues has a severe impact. Table 8 presents the importance with respect to the surroundings from the set of actions on each factor; the most important factor identified for both alternatives is the emission of particles, and specifically for the composting alternative the most important factors are gases, noises and vibration, and the quality of the landscape.

Table 7. Importance in relation to the surroundings from the effects due to Project related actions

Project Related Actions			Commercialization	Composting
CONSTRUCTION STAGE	A1	Movement of machinery	Irrelevant (-)	Irrelevant (-)
	A2	Movement of soil and clearing/removal	Moderate (-)	Moderate (-)
	A3	Construction debris	Irrelevant (-)	Irrelevant (-)
	A4	Transportation of materials	Irrelevant (-)	Irrelevant (-)
	A5	Power consumption	Irrelevant (-)	Irrelevant (-)
	A6	Fuel consumption	Irrelevant (-)	Irrelevant (-)
	A7	Water consumption	Irrelevant (-)	Irrelevant (-)

Project Related Actions			Commercialization	Composting
	A8	Drainage works and water storage	Irrelevant (-)	Irrelevant (-)
	A9	Land occupation	Irrelevant (-)	Moderate (-)
OPERATIONAL STAGE	A10	Occupation of the territory and the presence of buildings	Critical (-)	Critical (-)
	A11	Storage of rain water	Irrelevant (-)	Irrelevant (-)
	A12	Air renovation in the installations	Irrelevant (-)	Irrelevant (-)
	A13	Reception and storage of residues	Severe (-)	Severe (-)
	A14	Power consumption	Irrelevant (-)	Irrelevant (-)
	A15	Process water consumption	N/A	Irrelevant (-)
	A16	Consumption of water in bathrooms	Irrelevant (-)	Irrelevant (-)
	A17	Leachates	Irrelevant (+)	Irrelevant (-)
	A18	Compost hydration	N/A	Irrelevant (-)
	A19	Water treatment and reuse	Moderate (-)	Moderate (+)
	A20	Operation of machinery and equipment	N/A	Irrelevant (-)
	A21	Motor vehicles loading and unloading residues	Irrelevant (+)	Irrelevant (-)
	A22	Control of operational conditions	Moderate (+)	Severe (+)
	A23	Ground transportation of residues	N/A	Irrelevant (-)
	A24	Residues and refuse to landfill	Irrelevant (+)	Irrelevant (+)
	A25	Treatment of fermentable residues	N/A	Irrelevant (+)

Table 8. Importance in relation to the surroundings from the effects suffered by environmental factors

Sub-system	Component	Environmental Factors		Commercialization	Composting
Physical medium	Water	F1	Availability of water	Irrelevant (-)	Moderate (-)
		F2	Water quality	Irrelevant (-)	Moderate (-)
		F3	Underground water	Moderate (-)	Irrelevant (-)
	Atmosphere	F4	Odors (VOC)	Irrelevant (-)	Irrelevant (-)
		F5	Generation of gases	Moderate (-)	Critical (-)
		F6	Emission of particles	Severe (-)	Critical (-)
		F7	Luminic radiation	Irrelevant (-)	N/A
		F8	Noises and vibration	Moderate (-)	Severe (-)
	Soil	F9	Change of use	Irrelevant (-)	Irrelevant (-)
		F10	Changes in natural drainage	Irrelevant (-)	Moderate (-)
		F11	Infiltration by accidental discharges	Irrelevant	Irrelevant (-)
		F12	Land value	Irrelevant (-)	Irrelevant (-)
Biotic medium	Flora	F13	Changes in the vegetation	Irrelevant (-)	Irrelevant (-)
		F14	Diversity of species	Irrelevant (-)	Irrelevant (-)
		F15	Reduction of natural spaces	Irrelevant (-)	Irrelevant (-)
	Fauna	F16	Increase of noxious fauna	Irrelevant (-)	Irrelevant (-)
		F17	Pathogenic agents	Irrelevant (+)	Irrelevant (+)
		F18	Illness-insect vectors	Irrelevant (-)	Irrelevant (+)
Socio-cultural medium	Landscape	F19	Quality of the landscape	Moderate (-)	Severe (-)
		F20	Alterations and visibility	Moderate (-)	Moderate (-)
	Health	F21	Public health	Irrelevant (+)	Irrelevant (+)
		F22	Personnel health	Irrelevant (+)	Irrelevant (+)
	Employment generation	F23	Workforce demand	Irrelevant (+)	Irrelevant (+)

Sub-system	Component	Environmental Factors		Commercialization	Composting
	Urban development	F24	Management of residues	Irrelevant (+)	Irrelevant (+)
		F25	Investment in public services	Irrelevant (+)	Irrelevant (+)