



Green Leather Industry for the Environment (greenLIFE) is a project run by a group of industry partners in Italy's Arzignano tanning cluster. The project partners have committed to sharing their findings by publishing a series of papers in World Leather. This is the second of six greenLIFE articles.

greenLIFE 2: A novel Key Performance Indicator for the assessment of the liming process

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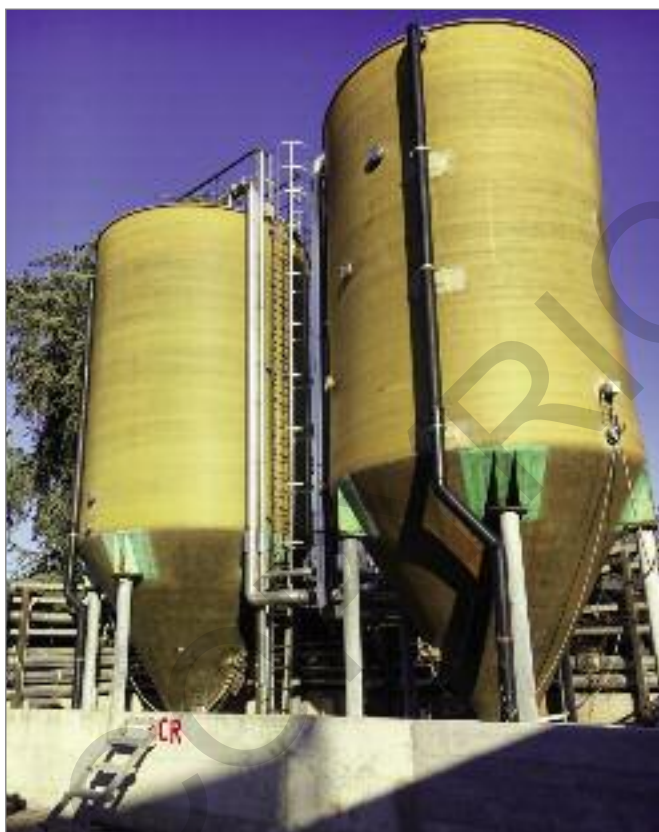


Figure 1: Storage tanks for the recovery of liming baths.

1. Introduction

As partner of the GreenLIFE LIFE13 ENV/IT/000840 European Project, Gruppo Mastrotto focused its activity on the improvement of the environmental sustainability of leather production by reducing the usage of chemicals and clean water in the liming process. To this purpose, the residual chemical reactivity of exhausted liming baths has been exploited by means of a partial closed-loop recycling of the wastewater. Water recycling is carried out by collecting the effluent discharged from the main liming process in a storage tank (Figure 1) and, after a primary

sedimentation, by reusing it in fresh liming floats in variable proportions to clean incoming water. The removal of floating hair from the unhairing bath (hair saving process) was also contemplated so as to further improve liming's environmental liability.

In order to quantitatively estimate the effect of the process modifications on the environmental impact, a numeric index, IA, has been conveniently defined and used throughout the whole course of the LIFE project. This expedient considerably simplifies the comparisons of the environmental effect of a number of different recipes where the percentage of chemicals, the water recycling ratio and the hair recovery were varied within defined ranges.

2. Liming process with reduced environmental impact

In the scope of the greenLIFE project the liming recipe has been subjected to variations in the amount of sulfide (usage of sodium sulfide) and of water recycled from previous liming baths. In the perspective of a reduced environmental impact an hair saving process was also implemented for some of the trials, as this generally implies a reduction of the organic load in the wastewater. (The recovered hair - Figure 2 - may also represent a valuable source of keratins made available for a number of technological applications, with additional positive



Figure 2: Hair recovered from unhairing process.



effects on the environment.)

The percentage amount of sodium sulfide in the unhairing recipe has been changed in the range 1.5-2.7 % wt., while the recycling ratio was set to two values, namely 100% and 30%, of clean water in the total liming float. Different settings of these factors have been explored during the project, giving rise to a corresponding number of trials. In all instances the water discharged at the end of the liming process was sampled and analysed in order to quantify some environmentally-significant parameters.

In devising the comprehensive environmental index IA, the results obtained from the wastewater analysis have been conveniently combined with a weighted average procedure; the values of sulfide usage and recovery ratio have also been included in the calculation in order to enlarge the amount of information gathered by the index. The complete list of the environmental parameters used to define IA is given in *Table 1*.

It should be noticed that, among the environmental variables, only the values of AP and SL can be freely chosen by design, while all the other parameters are obtained from the analytical evaluation of the wastewater.

Each of the variables described in *Table 1* ranges between a minimum and a maximum value that depend on the experimental background: for instance, the clean water rate ranges between a minimum value of 30% and a maximum value of 100% (corresponding to a recycling ratio of 70% and 0%, respectively). An overview of the values spanned by the environmental parameters is given in *Table 2*.

3. Definition of the environmental index IA

The environmental index is created as a non-dimensional figure ranging between 0 and 100, where larger values of the index tend to indicate a proportionally high environmental quality of the liming process (less environmental impact).

In order to calculate the index, each of the parameters listed in *Table 1* needs to be converted first into a correspondent reduced normalised variable with *Equation 1 (below)*:

$$x_i = \frac{(p_i - p_{\min})}{(p_{\max} - p_{\min})}$$

Table 1: Variables used to calculate the environmental index IA.

Variable	Description
AP	Rate of clean water vs. recycled bath (%)
SL	Amount of total offered sodium sulfide (% wt.)
COD	Chemical Oxygen Demand in the wastewater (mg/L)
SO	Sulfate concentration in the wastewater (mg/L)
CL	Chloride concentration in the wastewater (mg/L)
S2	Sulfide concentration in the wastewater (mg/L)
SS	Suspended solids in the wastewater (mg/L)
TKN	Total Kjeldahl Nitrogen in the wastewater (mg/L)

Table 2: Largest and smallest values of the environmental parameters across the project.

Parameter	AP	SL	COD	SO	CL	S2	SS	TKN
Unit	%	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Minimum	0	1.50	36200	53	4630	680	2340	1999
Maximum	100	2.70	89090	9468	23100	6020	73425	9300

Table 3: Values of the environmental parameters for trial no. 19.

Parameter	AP	SL	COD	SO	CL	S2	SS	TKN
Value	100	2.20	75400	550	18000	1050	69300	6730
Normalised value	1.00	0.58	0.74	0.05	0.72	0.07	0.94	0.65
Weight	10.00	4.06	5.94	1.03	5.72	1.04	8.99	4.78

where p_i is the value of the generic parameter p recorded at the i -th trial (for instance, for p = sulfate and i = 19 it corresponds to the concentration of sulfate in the wastewater of trial no. 19, that is 550 mg/L). The two values $p_{\max}$ and $p_{\min}$ are the maximum and minimum values of that same parameter that have been registered during the whole set of trials: for sulfate these correspond to 53 mg/L and 9468 mg/L, respectively (see *Table 2*). With this transformation all the original values are converted into an array of numbers ranging between 0 and 1 that can be consequently summed up and averaged. A statistical weight (w_i), the calculation of which is described by *Equation 2 (below)*, is also assigned to each variable.

$$w_i = 1 + 9x_i^2$$

Finally, the index IA is calculated with *Equation 3 (below)*:

$$IA = 100 \cdot \left(1 - \frac{\sum_{i=1}^p w_i x_i}{\sum_{i=1}^p w_i} \right)$$

The environmental rankings for trial number 19 are reported in *Table 3* as an example.

The result of the calculation for trial 19 (*Equation 3* fed with the figures in *Table 3*) comes out to be: $IA = 100 - 78.45 = 21.55$, that indicates a poor environmental performance. This is not surprising as in this case there was no water recycling ($AP = 100\%$) and high values for suspended solids SS (94% of their maximum value) and COD (74% of its maximum value) were found in the effluent water.

4. An applicative example

The environmental index defined in the previous sections is used here to evaluate the effect of different concentrations of offered sodium sulfide on the liming process. In this series of processes the recycled liming bath was mixed with clean water in a 70:30 ratio ($AP = 30\%$) for all trials, and the hair saving process (hair recovery) was carried out. The percentages of sodium sulfide used for unhairing within this experimental series are reported in *Table 4* together with the calculated values of IA.

The sulfide concentrations are listed in decreasing order as the experiments started with the highest amount of sulfide



and proceeded by lowering it in a progressive fashion as long as an acceptable leather quality was secured. As it is apparent from Figure 3, the environmental index IA appears to be approximately unchanged for most of the sulfide domain. The low value observed in correspondence with the highest amount of sodium sulfide (2.70% wt.) is due to the quadratic relationship used to calculate the statistical weights (Equation 2). In general terms, as long as sulfide is not adhering to its maximum concentration, the variable "total offered sulfide" (SL, Table 1) does not show a significant effect on IA within this experimental set-up (hair and bath recovery).

5. Conclusions

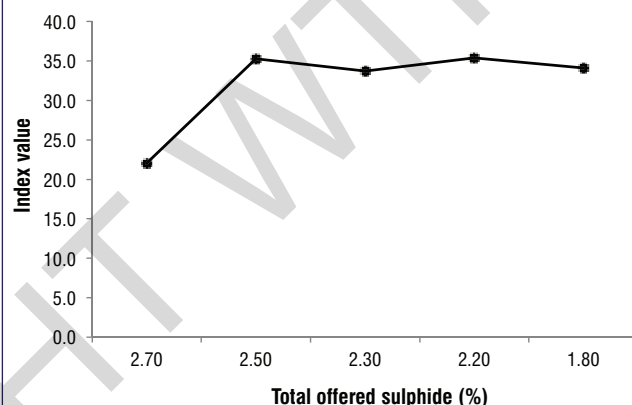
In this work the effect of modifications to the liming process has been assessed by means of a numerical index that incorporates a set of environmental parameters into one single KPI (key performance indicator). This has been developed as part of the greenLIFE project, where variations were introduced searching for a minimisation of the environmental impact, while safeguarding an adequate quality level of the leather. The environmental index is easily calculated starting from environmental variables that are measured during leather manufacture, and it can be extended to other segments of the tanning process by an appropriate choice of the environmental variables. Gauging the environmental performance with one single index is helpful when comparisons are made within an established process when some influential variables are changed. 🌱

GreenLIFE is part of a wider European Union initiative, LIFE13 ENV/IT/000840.

Table 4 – Environmental response of the system to added sulfide variation.

Offered sodium sulfide (%)	IA
2.70	22.03
2.50	35.26
2.30	33.71
2.20	35.41
1.80	34.09

Figure 3: Behaviour of IA as a function of sodium sulfide offer.



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