



SUSTAINABLE MANAGEMENT OF SOLID CHROME WASTE IN THE

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ABSTRACT

The tanning sector currently faces the urgent challenge of mitigating its environmental footprint, particularly due to the generation of chrome solid waste (SSD) during production. In the case study analyzed, this waste is disposed of without prior treatment, generating a significant ecological impact. This research proposes innovative solutions to reduce associated pollution and generate added value from waste. A technical and environmental assessment was conducted at the tanning stage, specifically in the splitting, and sizing operations, the main sources of SSD generation. This allowed for a detailed physicochemical characterization of the leather scrape, precise quantification of generated volumes and the assessment of specific environmental impacts. The proposed solutions represent a replicable model for the industry, combining environmental responsibility with economic profitability. This circular approach transforms an environmental problem into a sustainable business opportunity.



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I. INTRODUCTION

Cleaner Production (CP) practices are strategic for reducing environmental impacts and improving industrial efficiency. They aim to prevent, reuse, and reduce waste, emissions, and unnecessary consumption, optimizing resources such as water, energy, and raw materials. Their implementation contributes to environmental conservation and industrial sustainability [1-3]. The valorization of solid tannery waste offers economic and environmental benefits. Recent studies demonstrate that chromium shavings can be used as aggregates in mortars and concretes (5–15% substitution), improving mechanical properties and reducing density [4]. Additionally, [4],[5] reported acoustic properties with 20% shavings, while [6] highlight their potential in multifunctional sustainable materials. Processing leather scraps through hydrolysis allows for the production of biofuels, soaps, and hydrogels [7],[8], promoting a circular economy model [9]. The objective of this work is to develop a sustainable management of the solid chromium residue (RCS) through its use in alternative construction materials, based on previous studies.

II. THEORETICAL REFERENCE

II.1 SUBTITLE

II.1.1 Materials and Methods

The biggest problem identified in the assessment was the inadequate disposal of the leather or rasp shavings generated in this process. This waste is collected every 30 to 40 minutes and dumped in the facility's outdoor areas, along with other solid waste from other processes (trimming) that differ in characteristics, and with the remains of branches, leaves, etc. These chrome solid wastes have a significant negative impact on the soil, but the most significant is chromium, which can disrupt crop development. It is true that soils have a contaminant load neutralizing capacity, but when this load is exceeded, the adverse effects generated by these metals will begin to become evident. This results in the deterioration of soil quality and water resources (groundwater and surface water) due to the inadequate disposal of these residues [10].

III. MATERIALS AND METHODS

Calculation of the amount of solid waste generated in the scraping process.

To calculate solid waste, the split leather entering the process (batch) was weighed, and all the shavings generated during the process were collected and weighed. See Figure 1 (a and b).



Figure 1: Procedure for calculating the amount of RSC generated in the scraping process.
Source: Authors, (2026).

As a result of the measurements, the index was determined: 7.7% of the t/year to be processed, see Table 1. Of the total RSC generated, 58% is destined for the conglomerate factory (when said factory works at 100%) and 42% of the waste remains without adequate final disposal.

Table 1: Solid Chromium Residue (SCR).

Specific	t/a	%
Chrome shavings skin	123.12	6
Chrome chips recess	143.64	7
Total	266.76	7.7

Source: Authors, (2026).

Physicochemical characterization of the solid waste (body shavings or scrapings)

The following were determined from the scraped leather shavings: 1) Humidity; 2) pH; 3) Apparent density; 4) Ash percentage, 5) chromium oxide percentage and 6) optical microscopy (an XTJ-5700E stereoscopic microscope was used, coupled to a Canon Powershot A630 camera).

Laboratory-scale leaching tests in a flooded environment on natural chippings

Leaching processes in today's industry rely on tests that allow for slow control of production processes, as very long pilot test periods are required to provide data that can be used for daily operational decision-making and the evaluation of each company's own technologies. This test studies the leaching of chromium in the form of chromium oxide present in leather shavings into an aqueous medium. Its objective is to simulate the process that can occur when these residues are not properly disposed of. Leaching tests were conducted under the following conditions. 100 g of leather shavings tanned with basic chromium sulfate were added to a flask, bringing the total volume to 2000 ml of water (5% solids relative to the total volume). This is shown in Figure 2. During the leaching tests, a total of 13 samples were taken over a 7-day interval.



Figure 2: Experimental system used in the aqueous leaching test of leather shavings.
Source: Authors, (2026).

Use of chrome swarf for the production of construction materials

Considering the morphological characteristics of SCR (leather shavings or rasp), which, according to the microscopic study, showed it to be a fibrous material, it was decided to investigate its potential behavior as a reinforcing material in mortars and concretes made with Portland cement. In addition to evaluating its potential use as reinforcement to improve the physical and mechanical properties of agglomerates, it could be a practical way to immobilize chromium and prevent its possible leaching when used in outdoor applications, thereby mitigating the negative environmental impact. Mortars tests were performed on standard 4x4x16 cm specimens, both for mechanical strength assessment and for leaching studies. Cylindrical specimens measuring 10 cm in diameter and 20 cm in height were used to determine the compressive strength of the concrete. Finally, beam-shaped specimens measuring 20x20x60 cm were used to determine the properties of the concrete reinforced with leather chip fibers.

Laboratory-scale leaching tests in flooded media on chips in mortar and concrete specimens.

To perform a laboratory-scale aqueous leaching test, the material selected was parts of the mortar and concrete specimens tested in flexural and compression tensile strength after 28 days of curing. Distilled water was used as the leaching medium in a 1:5 ratio of solid to liquid. Finally, the sample was removed, and the pH and Cr_2O_3 concentration in g/L of the remaining water were determined. Figure 3 shows the experimental system used in the aqueous leaching test of the leather shavings incorporated into the mixtures.



Figure 3: Experimental system used in the leaching test in the aqueous leaching test of the leather chips incorporated into the mixtures.
Source: Authors, (2026).

Environmental impact assessment of the use of chromium swarf as a reinforcement material in mortar and concrete.

The environmental impact assessment was conducted according to the characterization models of the Recipe (H) methodology in the categories related to toxic effects, based on the information provided by the chemical characterization of the excess water from the leaching tests with the swarf in its natural state and within mortar and concrete specimens, using SimaPro v 9.035 software from Pre Consultant.

IV. RESULTS AND DISCUSSIONS

Results obtained in the physical-chemical characterization of the solid waste (leather shavings or scrapes).

The average values of the physical-chemical analytical results performed are reported in Table 2.

Table 2: Average values of the physical-chemical analytical results.

		
Analytical determination	Unit of measure	Average value
Color	-	Blue
Aspect	-	Spiral-elongated
Humidity	%	51.48
pH	u	4.82
Apparent density	g/ml	0.102
Ashes	%	4.93
Chromium oxide (Cr_2O_3)	%	2.62
Water absorption by total immersion	g water /g de SCW	2.9

Source: Authors, (2026).

The results obtained coincided (the % humidity) with the typical values found in [11],[12], given that tanned leather loses half of its humidity due to its draining process, leaving approximately 50-55%. The percentage of chromium oxides obtained are lower than those reported by [13],[14]. This is because in the tanning process carried out in the company under study, the chromium salt has been reduced to 5 - 6% on the haired skin as a P + L measure to reduce the negative impact that these residues cause to the environment. Previously, they worked between 6 - 6.5%. In the case of the % ash and pH, the results are similar to those obtained by [15] In the case of other authors the values are lower or not reported (e.g. pH).

Optical microscopy results.

Leather is composed primarily of collagen fibers or fibrous bundles whose interlacing forms the fibrous structure. The physical properties of leather result from the sum of the physical properties of the fibers and the weaving pattern. Figure 4 shows the structure of the leather shavings or scrapes under study. This is consistent with the literature report by [16] where it is observed that in an ordered weave, the fibrous bundles do not vary greatly in size or degree of division and are regularly intertwined.

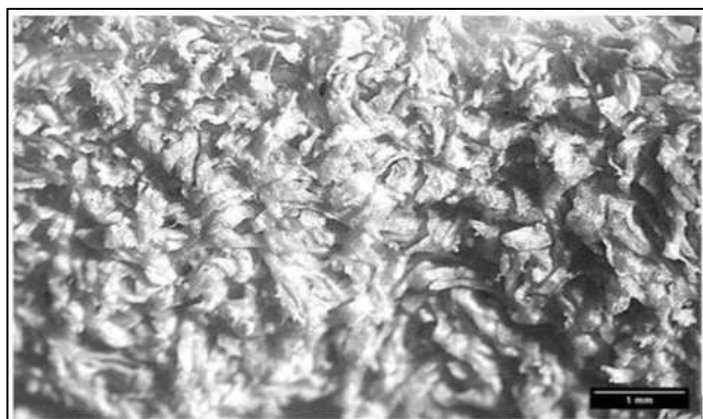


Figure 4: Structure of the leather shaving or scrape under study.

Source: Authors, (2026).

Table 3 shows the time intervals for sampling and the results obtained from the concentration of Cr_2O_3 in g/l in the leachate. Significant concentrations of this contaminant are observed in the leachate, which represents a risk of contamination of the soil and surface and groundwater due to the possibility of mobility of chromium and its transformation into more contaminating species such as chromium VI. This risk may increase in the presence of oxygen in the environment, since the predominant oxidation state of Cr, under conditions of excess oxygen, is hexavalent Cr (VI), and under anoxic conditions the trivalent Cr (III) species prevails. Hexavalent chromium (Cr (VI)) is produced almost exclusively in tetrahedral coordination with oxygen, as the chromate anion (CrO_4^{2-}). This species exists predominantly at pH values greater than 8.5. On the other hand, chromic acid (H_2CrO_4) easily loses its first proton, behaving as a strong acid; therefore, at pH values lower than 6.5, the monoprotonated species (HCrO_4^-) predominates. At concentrations higher than 0.5 M, this species tends to form the dichromate ion ($\text{Cr}_2\text{O}_7^{2-}$). The systemic toxicity of chromium is mainly due to its hexavalent derivatives, causing negative impacts on water, soil, and human health.

Table 3: Concentration of chromium III oxide (Cr_2O_3) in the leachate.

Time (d)	pH	M1	M 2	M 3	Average	Est. Desv.
7	4.95	0.0253	0.0247	0.0251	0.025	0.0003
14	4.5	0.0253	0.0252	0.0248	0.025	0.0003
21	4	0.05	0.048	0.051	0.050	0.0015
28	3.9	0.13	0.135	0.131	0.132	0.0026
35	4	0.1	0.11	0.11	0.107	0.0058
42	3.96	0.18	0.182	0.179	0.180	0.0015
49	3.87	0.0253	0.0251	0.0248	0.025	0.0003
56	3.95	0.13	0.134	0.132	0.132	0.0020
63	3.73	0.0506	0.051	0.052	0.051	0.0007
70	3.85	0.0759	0.076	0.0757	0.076	0.0002
77	3.77	0.18	0.181	0.179	0.180	0.0010
84	4.1	0.0253	0.0251	0.0254	0.025	0.0002
91	4.15	0.0253	0.0252	0.0254	0.025	0.0001

Source: Authors, (2026).

Table 4 shows no statistically significant differences in the concentration of Cr_2O_3 in the leachate between samples on different days of exposure ($p=0.7650$), with an average of 70 mg $\text{Cr}_2\text{O}_3/\text{l}$ across all samples (see Table 3). This demonstrates that leaching occurs from the first seven days of exposure of the waste to rainwater.

Results obtained from the use of chromium swarf for the production of construction materials.

In the studies carried out by [17] mixtures were used where the leather chip (fiber) content was varied by 0.2%, 0.5%, 1%, 1.15% and 1.5%. It can be seen in the results of the tests carried out, both on mortars and concretes reinforced with leather fibers from the tannery company under study, that with the increase in the fiber dose the flexural behavior is improved, but its compressive strength is slightly affected at doses of 0, 2.5 and 5.0 kg/m³.

The results of tests on concrete reinforced with leather chips showed that, as the flexural strength increased, the deformation values also increased. In the leaching tests of leather shavings incorporated into mortars and concretes, carried out by [17], it is evident that there is no presence of any chromium compound, either in the form of acids or chromatic ions that can react with water molecules or oxygen in the environment, given the non-detection of Cr_2O_3 in the chemical analyses carried out on the excess water used in the test. Considering the results obtained in the studies conducted on masonry mortars and concretes, the following recommendations for their use are given:

Recommendations for the use of mortars

- ✓ Mortars for various masonry applications (according to Cuban standard NC 175:2002 Masonry Mortars. Specifications), both indoor and outdoor.
- ✓ Mortars for the manufacture of slabs for use in joist and slab roofing systems.
- ✓ Mortars for the manufacture of floor tiles.

Recommendations for the use of concrete

- ✓ Concretes for the manufacture of hollow concrete blocks that meet the requirements established in Table 2 of NC 247:2010 Hollow Concrete Blocks – Specifications. That is: 7 MPa for Type I blocks and 5 MPa for Type II blocks, at 28 days of age.
- ✓ Concretes for the manufacture of paving slabs and lattices.
- ✓ Concretes for pavements or floors.
- ✓ Concretes for the construction of sidewalks and curbs.
- ✓ Concretes for foundations.
- ✓ Increase the percentage of fibers in the mixtures from 2% to 10%, determine the behavior, and compare it with research conducted by other authors using more than 10% fibers in concrete and mortar.

The percentage of fibers added to the mix in studies conducted by [17] is considered low compared to studies reported in the literature, [18] uses 8%–20% of hide shavings [10], 24%. In the latter case, significant changes in the performance curves are observed. Therefore, future research should increase the percentage of hide shavings (fibers) in the mixes from 2% to 10%, which allows evaluating the performance of concrete and mortar. This dual-purpose approach not only mitigates the environmental impacts of chromium waste, but also develops lightweight insulating materials suitable for non-load-bearing applications, such as insulating panels and boards and [11].

• Results of the environmental impact assessment of the use of chrome swarf as a reinforcing material in mortars and concrete.

The results show that under anoxic conditions, when the trivalent Cr (III) species predominates, the impacts are lower, both in terms of impact and damage. This demonstrates that the incorporation of chromium turnings into concrete and mortar eliminates the environmental impacts caused by unsustainable wastewater management.

Under conditions of excess oxygen when the hexavalent Cr (VI) species prevails

The environmental impact assessment results obtained using SimaPro v9.0.35 from Pre Consultant, Recipe (H) methodology are presented in Tables 4 to 7. The assessment considers the toxicological impact and damage categories associated with chromium under different environmental conditions. DBE represents dichlorobenzene equivalent, the reference substance used for the toxicity-related impact categories. Under anoxic conditions, where Cr(III) is the predominant chromium species, the characterization results for the selected environmental impact categories are presented in Table 4. The corresponding damage assessment for human health and ecosystems is summarized in Table 5. Under oxygen-rich conditions, where Cr(VI) may predominate, the environmental impact characterization results are presented in Table 6. The corresponding damage assessment, expressed in terms of human health and ecosystem damage categories, is presented in Table 7.

When chromium is in the form of Chromium III (under anoxic conditions)

Table 4: Environmental impact characterization results for Cr(III) under anoxic conditions.

Impact categories		Unit
Terrestrial Ecotoxicity	1.09E-16	kg 1,4 DBE*
Freshwater ecotoxicity	2.30E+00	kg 1,4 DBE*
Marine ecotoxicity	2.17E+00	kg 1,4 DBE*
Human carcinogenic toxicity	4.00E+02	kg 1,4 DBE*
Non-carcinogenic human toxicity	3.08E+00	kg 1,4 DBE*

Source: Authors, (2026).

Table 5: Damage assessment results for Cr(III) under anoxic conditions.

Damage analysis		
Damage categories		Unit
Salud humana	22.4	pt
Ecosistemas	0,00102	pt

Source: Authors, (2026).

When chromium is in the form of Chromium VI (under conditions of excess oxygen)

Table 6: Environmental impact characterization results for Cr(VI) under oxygen-rich conditions.

Impact categories		Unit
Terrestrial Ecotoxicity	2.76E-21	kg 1,4 DBE*
Freshwater ecotoxicity	5.97E-05	kg 1,4 DBE*
Marine ecotoxicity	3.80E-05	kg 1,4 DBE*
Non-carcinogenic human toxicity	2.91E-06	kg 1,4 DBE*

*DBE: Dichlorobenzene equivalent, reference substance for impact (toxicity) categories.

Source: Authors, (2026).

Table 7: Damage assessment results for Cr(VI) under oxygen-rich conditions.

Damage analysis		s
Damage categories		Unit
Human health	11.2	Pt
Ecosystems	25.4	Pt

Source: Authors, (2026).

The results obtained in both the impact and damage categories show that systemic chromium toxicity is mainly due to the hexavalent derivatives (chromium VI). The highest values observed in the human health damage category. This is because they can penetrate the body by any route more easily than trivalent derivatives (Cr III), and are a recognized carcinogen (human carcinogenic toxicity: 4.00E+02 kg 1.4 DBE). However, significant risks associated with trivalent chromium (chromium III) have also been documented. However, to achieve toxicity equivalent to hexavalent chromium, higher doses needed because they do not have the ability to penetrate living organisms. In the case of trivalent derivatives (Cr III), the greatest damage is to the ecosystem (25.4 Pt). Skin contact with certain chromium (VI) compounds can cause skin ulcers and allergies. Some people are very sensitive to chromium (VI) and chromium (III), experiencing severe skin redness and swelling. When this metal is present in the soil, it can follow four different pathways: first, be retained in the aqueous phase of the soil; second, it can be absorbed onto inorganic soil constituents; third, it can be associated with soil organic matter. Finally, it can precipitate as pure or mixed solids, or, in most cases, absorbed by plants, pass into the atmosphere by volatilization, and move through groundwater and surface water, contaminating them [19]. In addition to soil acidification, it can also influence chromium uptake by crops [9]. The presence of industries around rivers and direct discharges without prior wastewater treatment result in high concentrations of this pollutant in the receiving basins and surrounding ecosystems, affecting both the waters and living beings in the area. This is evident in the results obtained in both the impact and damage categories.

V. CONCLUSIONS

Based on the results of laboratory tests for both mechanical strength and chromium leaching, recommendations have been established for the potential applications of mortars and concretes reinforced with leather fibers. These alternatives reduce environmental impact across various damage and impact categories, facilitating sustainable management of the SCR generated by the industry. This lays the foundation for greener and more sustainable construction practices.

Interest Conflicts

The authors declare that there are no conflicts of interest.

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VI. AUTHOR'S CONTRIBUTION

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