LCA is more than an abbreviation: it's transparency, efficiency, and better business

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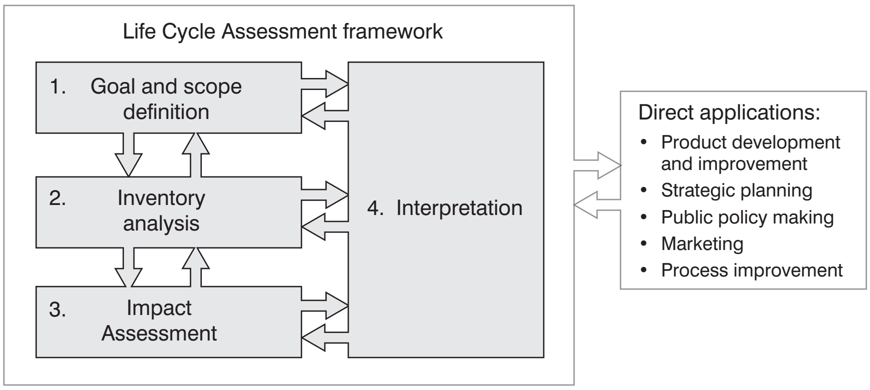
Life Cycle Assessment (LCA) is a method used to evaluate the environmental impacts of products and services throughout their entire life cycle, from raw material extraction to final disposal. It helps improve resource efficiency, reduce emissions, and support waste management practices. Trumpler, the German chemical company headquartered in Worms, Germany, applies LCA methodologies to assess the environmental performance of its chemical products, contributing to greater transparency and data-driven decision-making. By implementing LCA, opportunities for reducing environmental impacts and enhancing sustainability across the supply chain can be identified and addressed. It also should be noted that more brands and businesses are requiring such information.

Life Cycle Assessment (LCA) involves analysing the environmental impacts of a product or service at every stage of its life cycle, from the extraction of raw materials to its final disposal[1,2]. This entails considering every step of the process, from the extraction of raw materials to the ultimate disposal of waste, including the stages of manufacture, transportation, usage, and recycling. Both ISO 14040[3] and 140444[4] serve as standards for it.

LCA is essentially the balance of materials and energy of the examined product system plus an evaluation of the possible environmental effects of the inputs (material and energy consumption) and outputs (air, soil, and water emissions) of the same system. Altogether, it provides a comprehensive and holistic view of the environmental loads of products and services under study, covering a wide set of environmental performance indicators such as global warming potential (GWP), acidification potential (AC), eutrophication potential (EP), ozone layer depletion potential (OLDP), human toxicity potential (HTP) or ecotoxicity potential (ETP).

LCA consists of the following crucial steps *(Figure 1)*:

Figure 1: Steps towards Life Cycle Assessment



1. Definition of goals and scope[5]: The goals of the analysis are established, and the elements and stages of the life cycle that will be covered are decided.
2. Life cycle inventory: Data on the inputs and outputs of every step of the life cycle is gathered.
3. Life cycle impact assessment: This involves evaluating any possible environmental effects linked to the selected inputs and outputs.
4. Results interpretation: Interpreting the data to pinpoint areas that need improvement and offering solutions that will have the least negative effects on the environment is the most crucial step.

Trumpler values the importance of life cycle assessment (LCA) methodology in making data-driven decisions related to sustainability. This approach helps in identifying opportunities for enhancing resource efficiency, reducing emissions, and improving waste management practices.

The role of LCA in the leather industry

LCA in the leather industry is essential to assess the environmental impacts at each stage of the production process, from raw material extraction to manufacturing and final disposal[6,7,8]. Chemical manufacturers in the supply chain support such analysis. The implementation of LCA in the leather industry presents several challenges and opportunities.

The challenges include:

- **Obtaining accurate and complete data at each stage of the leather life cycle**: Many different stakeholders are involved in a value chain. Quantifying a company's own energetic and physical inputs and outputs is feasible, though it can be costly in some cases. However, obtaining extensive data from external stakeholders remains challenging.
- **Investment in technology**: Small- and medium-sized businesses may struggle to implement life cycle assessment due to the costs associated with technology and training.
- **Waste and emissions management**: One of the biggest challenges in the tanning industry is effectively managing waste, particularly hazardous chemicals, and reducing emissions of greenhouse gases and other pollutants.

On the other hand, opportunities include:

- **Reducing environmental Impacts**: LCA helps to identify the most critical environmental impacts and focuses on minimising these effects. This encourages more sustainable and resource-efficient practices.
- **Resource optimisation**: LCA enables more efficient resource management, which can lead to long-term cost savings.
- **Waste reduction**: LCA promotes the reuse of materials and helps to minimise waste, contributing to a circular economy.
- **Market differentiation**: Implementing LCA can position companies as leaders in sustainability, appealing to environmentally conscious consumers and helping ensure compliance with environmental regulations and international standards.

In summary, while the leather industry faces several challenges in implementing LCA, it also presents numerous opportunities to enhance sustainability, efficiency, and competitiveness for both companies and the leather material itself.

Methodology

Trumpler assesses the LCA of chemical products following the requirements of ISO 14044:2006 – Environmental Management standard. The product category rules (PCR) applied are the PCR of Basic Chemicals Version 1.0 (2021:03).[9]

This study presents the LCA assessment of 15 chemical auxiliaries manufactured by the Trumpler group and produced at its manufacturing site located in Barberà del Vallès. Of the 15 products, nine are liquid retanning agents and six are powder retanning agents. We consider collagen hydrolysate, obtained from chromium shavings, to be an intermediate of which we have also developed a LCA, and which is one of the core components of commercial products. *Table 1* summarises the products examined in this contribution *(see also Figure 4)*.

Table 1: Chemical products examined in this contribution

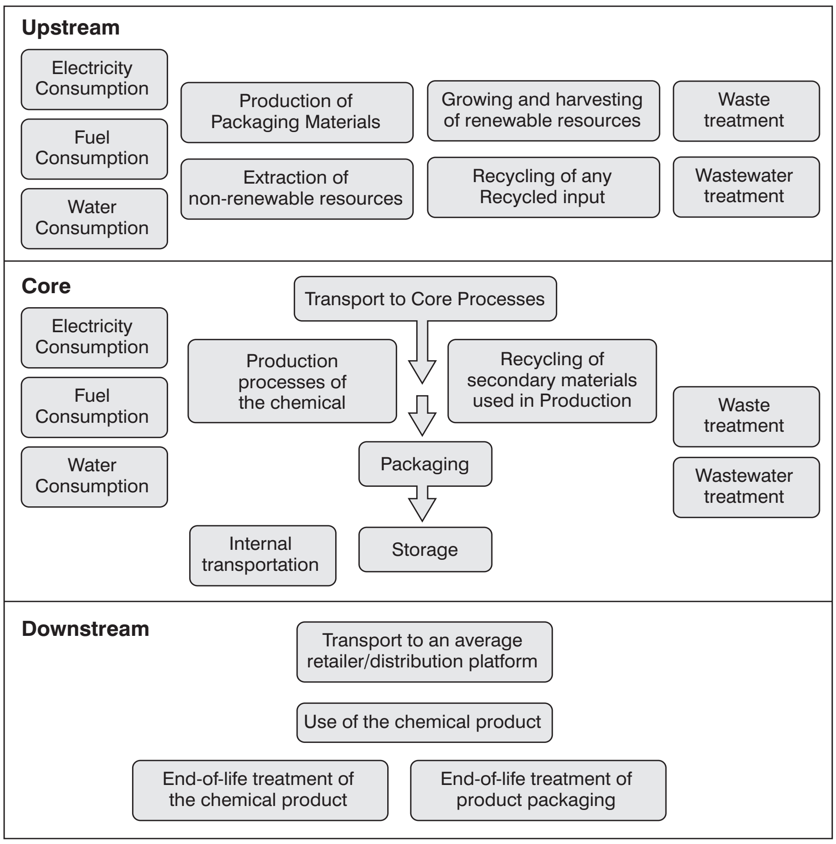
Product identification	Product category	Product nature
PR1-PR7	Liquid retanning agents	Fossil based
PR8 BIO – PR9 BIO	Liquid retanning agents	Biobased*
PR10 BIO – PR13 BIO	Powder retanning agents	Biobased*
Phenolic resin	Powder retanning agents	Fossil based
Melamine resin	Powder retanning agents	Fossil based

** Based on hydrolysed wet-blue shavings*

The study adopts a "cradle-to-grave" approach, utilising the principles of limited information loss at the final product stage. The analysis covers the following stages: upstream, core, and downstream. The processes within these established boundaries are illustrated in *Figure 2*.

We utilise two software programs: GaBi (Sphera)[10] and SimaPro[11] (pre-consultants). These programs are linked to two internationally recognised databases of life cycle information, including greenhouse gas (GHG) emissions: GaBi from Germany and ecoinvent from Switzerland[12] . Ecoinvent is among the most comprehensive and widely used environmental databases

Figure 2: Schematic overview of a "cradle to grave" approach.

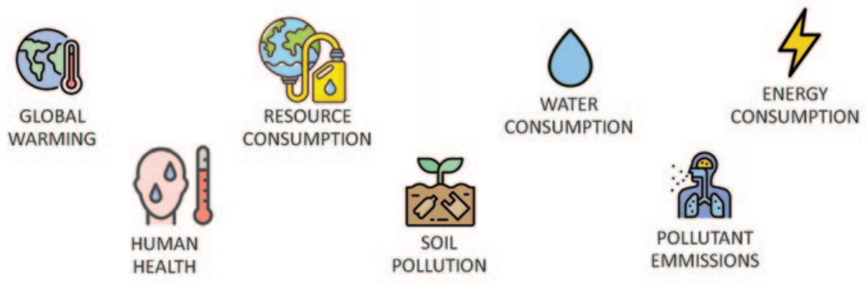


globally, offering life cycle inventory (LCI) data for a diverse array of products and processes, including energy, transport and waste management. GaBi is another well-regarded database that provides detailed life cycle data on various products and processes, known for its accuracy and extensive coverage of industrial sectors.

Using LCA databases provide accurate and reliable data that are essential for conducting thorough life cycle analyses. These databases facilitate the standardisation of LCA studies, enabling more consistent comparisons between different products and processes. Our calculations were primarily based on experimental data obtained during the production of the intermediates synthesised at Trumpler. Key data in this context include information on energy inputs (such as electricity and heat), water consumption, process material usage, and waste creation and disposal. The intermediate materials produced mainly serve as the foundation for our commercial products and, in some cases, are sourced from by-products of the leather industry, such as chrome shavings.

To maintain consistency, this study uses a declared unit of 1kg of chemical product, including its packaging.

Figure 3: LCA impact categories



Environmental impact identification

The selection of methods to measure the environmental impacts and the impact categories follows the criteria described in the product category rule (PCR). The environmental performance of the products evaluated in this study has been calculated using the EN 15804 +A2 impacts assessment method[13] *(Figure 3)*.

The results of the various products evaluated were analysed using GaBi Professional Software. Four key environmental impacts were identified as the most significant: Global warming potential (GWP), eutrophication in freshwater (EP-freshwater), soil quality potential (SQP), and abiotic depletion potential for fossil fuels (ADPF).

Global warming is driven by human emissions of greenhouse gases. The primary contributors to this warming are carbon dioxide (CO_2) and methane (CH_4), which account for over 90% of these emissions. The main source of these greenhouse gases is the burning of fossil fuels for energy.

The consequences of climate change include rising temperatures, an increase in the frequency of droughts and wildfires, shifts in rainfall patterns, melting glaciers and snow, and a rise in global sea levels.

Eutrophication is the process where freshwater bodies such as seas, lakes, rivers, and streams become overloaded with nutrients, primarily nitrogen and phosphorus. This can lead to a range of negative effects. Phosphorus (P) is the key nutrient responsible for eutrophication in freshwater environments. The impact of eutrophication is measured by the fraction of nutrients reaching freshwater, expressed in kilograms of phosphorus equivalents [kgPeq.].

Soil quality can be assessed using a soil quality index, which considers factors such as abiotic production, erosion resistance, and mechanical filtration. This index is based on the content of soil organic matter and is expressed in points [Pt] according to the model developed by Milà i Canals (2007)[14].

ADPF: This indicator evaluates the use of resources with energy carriers from fossil fuels and is measured in abiotic depletion factor-fossil fuels and expressed in MJ.

Results

While the overall impact of the chemical products is relatively similar across the four most relevant indicators (global warming, ecotoxicity of freshwater, land use, and fossil resources), this finding suggests that we can improve the environmental performance by focusing on these areas.

The most significant environmental impacts across all products are associated with the production of raw materials and packaging, see *Figure 4. Table 2* shows the contribution of different stages to the total GWP for products PR1-PR9.

The calculations revealed that products primarily composed of fossil-based raw materials, such as acrylic polymers and their derivatives (PR1-PR5), have a higher carbon footprint. Notably, acrylamide-based polymers (PR6) exhibit an even higher carbon footprint than acrylics. This is largely because acrylamide production typically involves the hydrolysis of acrylonitrile, a process that is energy-intensive and generates significant emissions. In contrast, acrylic acid is primarily produced through the oxidation of propylene, a method that, while also

Figure 4: GWP of the examined products *(see Table 1)*

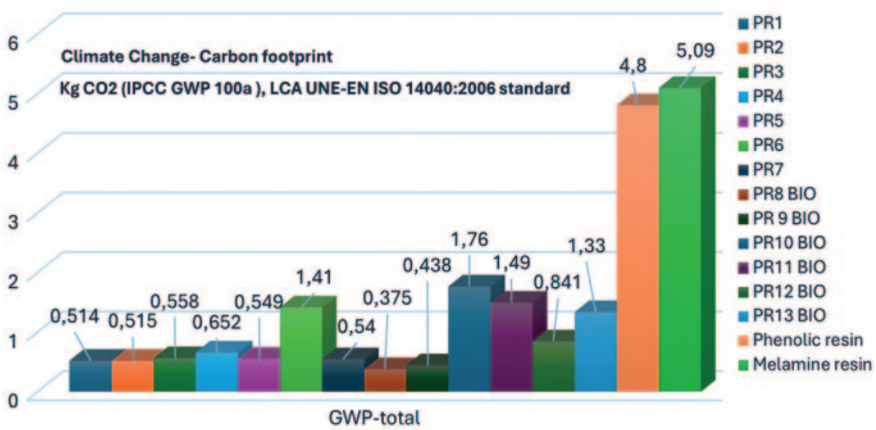


Figure 4 summarises the GWP of the products examined in the study.

consuming energy, is generally more efficient in terms of emissions.

Powder retanning auxiliaries made from protein hydrolysates (PR10-PR13) display lower carbon footprints compared to products derived from non-renewable sources such as synthetic resins. This reduced impact is due to the use of proteins sourced from recycled materials, specifically residues from leather processing. Utilising recycled materials minimises the need to extract and process new raw materials, which in turn lowers greenhouse gas emissions. As shown in *Table 2,* the environmental impact of raw materials significantly decreases from 72-89% (PR1 – PR7) to 59-67% (PR8 BIO and PR9 BIO) when renewable raw materials are incorporated.

Our study also found that chemicals derived from bio-based raw materials have a more positive impact on soil quality compared to those from fossil sources, indicating the beneficial effects that biomass from plants has on soil health. However, it is worth noting that raw materials derived from crops can lead to greater eutrophication due to the environmental effects of cultivation practices and the use of fertilisers.

In alignment with our commitment to sustainability and innovation, we are dedicated to producing low-carbon footprint products, such as bio-based chemicals derived from renewable raw materials. These initiatives reflect our dedication to aligning business practices with the United Nations Sustainable Development Goals (SDGs) and actively reducing greenhouse gas (GHG) emissions.

Table 2: Most relevant stages (GWP-Total)

Product	Electricity	Natural gas	End of life	Packaging	Raw materials	Transport
PR1	0%	0%	0%	25%	75%	0%
PR2	0%	0%	0%	25%	75%	0%
PR3	0%	0%	0%	25%	75%	0%
PR4	0%	0%	0%	20%	80%	0%
PR5	0%	1%	2%	23%	72%	2%
PR6	0%	0%	1%	10%	89%	0%
PR7	0%	1%	3%	10%	86%	0%
PR8 BIO	0%	1%	3%	35%	59%	2%
PR9 BIO	0%	0%	1%	30%	67%	2%

LCA a long way to go

Chemical life cycle assessment is set to become an even more vital tool for environmental management and sustainability in the future. The integration of advanced technologies, such as artificial intelligence and big data, will be essential for enabling more accurate and efficient data collection and processing, ultimately enhancing the precision of life cycle assessments.

Blockchain technology can simplify data collection for life cycle assessments by increasing transparency and traceability within the chemical supply chain. As environmental regulations are expected to become stricter, businesses will be compelled to employ LCA to comply with both local and international standards. For example, environmental certifications like ISO 14040 will remain crucial in demonstrating a company's commitment to sustainability.

LCA will be instrumental in facilitating the transition to a circular economy by helping to identify opportunities for the reuse and recycling of chemicals. Companies will leverage LCA to design chemicals that are easier to recycle and have a reduced environmental impact throughout their life cycle.

Businesses will also need to be transparent about the environmental impacts of their products, using LCA to effectively communicate their sustainability efforts to consumers. As awareness and education about the importance of LCA grows among consumers and stakeholders, the demand for more sustainable products will likely increase.

Furthermore, LCA will be beneficial in the research and development of alternative, more sustainable raw materials, allowing companies to assess their viability and environmental impact. Organisations will employ life cycle assessment to optimise their production processes, reducing emissions and resource consumption.

Collaboration among industry stakeholders, governments, and consumers is essential to address these challenges. Promoting the widespread adoption of sustainable chemical products, favourable regulations, ongoing innovation, and increased consumer awareness are critical. LCA will undoubtedly play a significant role in this endeavor.

Conclusions

A life cycle assessment can identify environmental impact hotspots within a product's lifecycle, allowing potential improvements to be identified and implemented.

LCA provide credible data to justify sustainable claims. When making environmental statements, robust LCA data enhances credibility and transparency. The data provided can substitute proxy values.

In the leather chemical industry, a Life Cycle Assessment fosters collaborative relationships with suppliers and tanneries. These studies promote greater transparency within the leather supply chain.

LCA offers a quantitative foundation for sustainability strategies, enabling organisations to make informed decisions. By understanding the environmental impact of chemical products, companies can develop more effective sustainability plans that enhance the ecological reputation of leather in the public eye.

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