Performing sustainable

Criteria for eco-friendly additives

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Although additives make up only a small part of a formulation, they must comply with the same environmental principles and regulations as the coating as a whole. Factors relevant to assessing the environmental impacts of additives are identified and discussed.

Environmental issues affecting paints and plastics are becoming increasingly important, and consequently additives must comply with the same environmental regulations as paints and coatings. These essential components of the chemical speciality industry are applied in paints, printing inks, plastics and paper coatings to optimise the production process and improve the quality of the final products.

Despite the fact that the amount of an additive in the final formulation is only around 1 %, its impact on the final product is extremely high, as for example on scratch resistance, gloss and haze. Nevertheless, their composition should not be disregarded.

Over the last few years, “green additives” have been introduced to the market. But what does “green” really mean? The first things that spring to mind are renewable resources, energy efficiency or eco-products. However, there is no universally accepted definition of what constitutes “green” or “green additives”.

In order not to confuse customers unnecessarily, it is recommended that standard criteria for “green additives” be implemented. Six criteria that emerge from the additive manufacturer’s point of view are presented below.

Criteria #1: VOC content

Environmental damage caused by VOCs (volatile organic compounds) has increased rapidly, and one of the main producers of these contaminants is the construction industry: sealants, adhesives, and coatings release VOCs into the air and harm people and the environment. Thus, reduction of VOCs is a key task for any additive manufacturer.

It should also be noted that the procedure for determination of VOCs in Europe and the USA is different: in Europe, VOCs are measured using headspace gas chromatography; in the USA, gravimetric analysis is employed. Because of the importance of this issue, a low VOC content is a good indicator of green additives, and in many cases products with a low VOC content are available as alternatives to established higher VOC products.

Criteria #2: different ecolabels

Ecolabels are an easy way to communicate the fact that an end product is environmentally friendly. These systems are based on different evaluation criteria, depending on the country or area from which they originate. Although the labels are available only for finished products, additives must meet the same criteria so that they do not adversely influence the end products.
It is important that these labels should not be undervalued, as they can considerably influence the purchasing decisions of end consumers. Examples of these ecolabels are the "EU Ecolabel" or the U.S. "Green Seal".

Criteria #3: implementation of renewable resources

Renewable resources are among the first things associated with the issue of "sustainability." A natural resource is classified as renewable if it is replaced by natural processes at a rate comparable to or faster than its rate of consumption by humans. In addition, some inorganic substances such as water or silicon dioxide are classified as "neutral" if they are not affected by incineration or biodegradation.

Quotation from ISO 14040: "LCA is a technique for assessing the environmental aspects and potential impacts associated with a product, by:

- Compiling an inventory of relevant inputs and outputs of a product system;
- Evaluating the potential environmental impacts associated with those inputs and outputs;
- Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study"[1]

Figure 1: Definition of an LCA according to ISO 14040

Renewable compounds for wetting and dispersing additives could be, for example, fatty acid esters/amides, phospholipids or high molecular weight alcohols that are 84 % renewable. For surface additives, natural waxes that are between 70 % and 100 % renewable are considered as environmentally-friendly resources.

Criteria #4: the issue of biodegradation

Biodegradation is the chemical breakdown of materials by environmental processes. This means that the materials will be restored to nature after its life cycle is complete. For example, there are unsaturated fatty acid amides for wetting and dispersing additives. These substances are 100 % biodegradable.

Results at a glance

››› Coating manufacturers must deal with stricter environmental legislation and increasing consumer interest in the environmental impacts of products. Though additives form only a small part of a formulation, they must comply with the same principles as the coating as a whole.

››› However, there is no universally accepted definition available of "green" and it is recommended that standard criteria be implemented for "green additives".

››› The six environmental criteria currently used are Ecolabels, VOCs, renewable resources, biodegradation, life cycle assessment and product carbon footprint.

››› The further development of eco-friendly coatings will continue, and in this situation additive manufacturers must play their part in developing appropriate products.

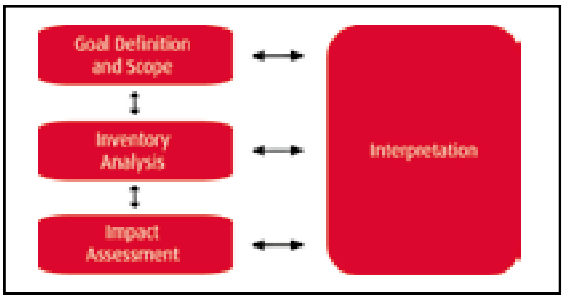

Figure 2: Phases of an LCA and their inter-relationships [2]

There are several test methods used to measure biodegradability. It is necessary to check which methods are compatible with the substance being tested. It should also be noted that biodegradation is an important factor in chemical regulation such as REACh.

Criteria #5: methodology of the life cycle assessment (LCA)

In the last 30 years, a new tool has been developed to present environmental information about products. This tool is called "life cycle assessment" and it reflects the environmental pollution that is caused during the full life cycle of a product. The life cycle begins with the extraction and supply of raw materials and ends with the recycling and return of the product to the environment. This approach is designated as "cradle-to-grave".
Here it should be noted that an additive manufacturer is a business-to-business company, and the "cradle-to-gate" approach is the better option to evaluate the product itself. "Cradle-to-gate" means from the extraction and supply of raw materials ("cradle") until the end of the production process in the company's factory ("gate") [1].
The life cycle assessment is defined by the international standards ISO 14040 and ISO 14044 (see *Figure 1*) and is divided into four phases (*Figure 2*) [2]:

Goal definition and scope

The "goal definition and scope" phase includes important information about the goal for the LCA study, the system definition and its boundaries and the assumptions that have been made.

Inventory analysis

The "inventory analysis" phase contains information about all flows (materials, energy, and emissions) that go into and out of the defined system.

Impact assessment

In the "impact assessment" phase, the information obtained from the inventory analysis will be evaluated using so-called impact categories. This provides the link between environmental impact and a product system.
According to the US EPA guide, there are only the three mandatory steps for an LCA [2]:
» Selection and definition of impact categories;
» Classification (assigning the impact assessment results to the impact categories);
» Characterisation (converting the impact assessment results into one defined unit and summarising them to form a representative impact category).
The calculations for the impact assessment can be handled with specific software instruments, such as GaBi 4, SimaPro 7 or Umberto 5. These tools work with databases that contain verified data sets.
In addition, it is possible to choose the impact category that is output by the software. On the one hand, there are midpoint methods which are a problem-oriented approach (e.g. Global Warming, GWP_{100}). On the other hand, there are the endpoint methods which are a damage-oriented approach (e.g. human health, Eco-Indicator 99 by PRé Consultants B.V. [3]) [4].
The most widely accepted midpoint method in Europe is the method proposed by CML (Centrum voor Milieukunde Leiden [4]) and its key aspects are shown in *Table 1.*

Interpretation

The last main phase is "interpretation". It reflects the whole life cycle assessment and can be divided into three steps [2]:
» Identification of the really important parts of the whole LCA;
» Check for completeness and consistency;
» Conclusion and reporting of all information of the LCA.
With these four steps it is possible to create a life cycle assessment for additives. A first screening result for two defoamers was made in co-operation with PE International GmbH 2010. It is the first attempt to create an LCA for additives and to demonstrate the environmental impacts of their life cycle from cradle to gate.
Figure 3 shows evaluations of two different defoamers. One additive is based on vegetable oil derivatives and has a significantly lower impact on the GWP_{100} than the mineral oil-based defoamer. Moreover, the biobased defoamer is both VOC-free and biodegradable, and it meets the required regulations for ecolabels worldwide.

The product carbon footprint – a simpler alternative to LCAs?

A more customer-friendly way to present the environmental impact of products is the "carbon footprint". The product carbon footprint is a way to describe the green-

Table 1: Environmental impact categories according to the CML system (R11 = CCl_3F; ** DCB = 1,4-dichlorobenzene)*

CML impact category	Abbreviation	Unit
Abiotic depletion (elements)	$ADP_{elements}$	kg Sb equiv.
Abiotic depletion (fossil fuels)	$ADP_{fossil\ fuels}$	MJ
Global warming (100 years)	GWP_{100}	kg CO_2 equiv.
Ozone layer depletion (steady state)	$ODP_{steady\ state}$	kg R11* equiv.
Human toxicity	HTPinf	kg DCB ** equiv.
Freshwater aquatic ecotoxicity	$FAETP_{inf}$	kg DCB equiv.
Marine aquatic ecotoxicity	$MAETP_{inf}$	kg DCB equiv.
Terrestrial ecotoxicity	$TETP_{inf}$	kg DCB equiv.
Photochemical oxidation	POCP	kg ethylene equiv.
Acidification	AP	kg SO_2 equiv.
Eutrophication	EP	kg PO_4^{3-} equiv.

house gas emissions over a product's life cycle (with the additive manufacturer adopting the "cradle-to-gate" approach as part of the overall assessment). It is equivalent to the global warming GWP_{100} impact category with the unit kg CO_2 eq. [5].
It would be wrong to state that the product carbon footprint is a "light version" of an LCA, but rather are faced of it.t is the same procedure for getting a result. At present there is no international standard for product carbon footprints, but the International Organization for Standardization is developing one [6].

First steps on the path to greener additives

The design of eco-friendly products is still in its beginning; supply-chain manufacturers are being pushed by the market to provide easy and more transparent information. It is the responsibility of the manufacturers to make verified and helpful data available.
Although work is only beginning, there exists an extensive database relating to VOCs, renewable resources, ecolabels, and biodegradation.
Life cycle assessment has recently been recognised as an important method. First steps are being taken to develop and collect specific data for a life cycle assessment of additives. It is expected that there will be valid data sets for numerous products available in the next two years.
Over the next few years, the demand for eco-friendly additives will increase significantly.
The debate about environmental protection and sustainability is triggered by new ideas and alternatives. In addition, consumers' views are changing. Even today, environmentally friendly products are assuming a more significant position than 20 years ago.
The development of eco-friendly coatings will continue. The goal of additive manufacturers should be to provide customers with solutions that enable them to formulate eco-friendly paint and coatings, both now and in the future.

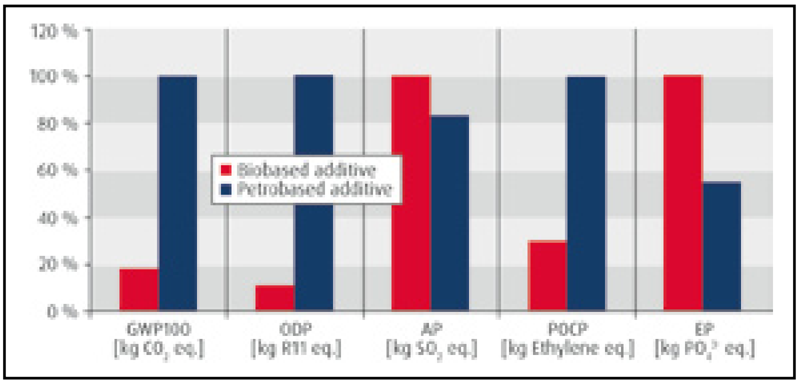

Figure 3: Results of an LCA assessment on two additives (GWP = Global warming potential; ODP = ozone depletion potential where R11 is CCl_3F; AP = acidification potential; POCP = photochemical ozone creation potential; EP = eutrophication potential)

REFERENCES

[1] *Frankl P., Rubik F.*, Life Cycle Assessment in Industry and Business: Adoption Patterns, Applications and Implications, Springer-Verlag 2000.
[2] Life Cycle Assessment: Principles and Practice, U.S. EPA, 2006, www.epa.gov/nrmrl/lcaccess/lca101.html.
[3] *Goedkoop M., Spriensma R.*, The Eco-indicator 99: A damage oriented method for Life Cycle Impact Assessment, 2001, www.pre.nl/content/reports.
[4] *Guinée J. B. et al.*, An Operational Guide to the ISO Standards, 2002, http://cml.leiden.edu/research/industrialecology/research-projects/finished/new-dutch-lca-guide.html.
[5] Guide to PAS 2050: How to assess the carbon footprint of goods and services, Carbon Trust, 2008, http://shop.bsigroup.com/en/Browse-by-Sector/Energy--Utilities/PAS-2050/
[6] www.pcf-world-forum.org/partner/iso-14067-carbon-footprint-of-products/