Modification and consistency -
about the sustainability factor of raw materials and products

A patent on the creation of substances

For millions of years, the patent on the creation of substances was owned by nature. All mineral or organic matter emerged without the initiative of the creatures that populated the world. Even the rising awareness of the self, several thousand years ago, did not change that: The early conscious human being's abilities to create new substances by way of chemical change was confined to very simple modifcations, mainly by heating.

Since then, the picture has changed. More and more, man has contested nature's monopoly on the creation of substances. So revolutionizing were these newly won abilities to create substances that complete epochs were later named after the resulting materials, e.g. the Bronze Age that has its name from the copper-tin alloy that was discovered then.

Still the most complex field of natural materials was mostly inaccessible to man, namely the realm of organic matter, i.e. basically carbon-based, complex matters like pigments, waxes, resins, oils, pharmaceutical agents etc. that mainly emerge in plants or through the metabolism of animals (like beeswax or milk protein).

It was not before the middle of the 19^{th} century that this central key patent of nature was also infringed. For the first time, chemists synthesised organic matters from an industrial waste-product, namely coal tar. First they produced dyes, then pharmaceuticals and other synthetic products that nearly completely replaced the unique natural materials originally used in these fields.

In the course of the 20^{th} century, tar was replaced by petroleum as the basis of synthetic chemistry. Petrochemistry was born and has been the main source for the organic chemicals in our everyday products ever since. Washing agents, textile fibres, a colourful paint variety - most people are not aware of the fact that pure fossil raw materials are the basis of everyday chemistry.

Sustainability problems of petrochemistry

Petrochemicals are based on the non-renewable raw material petroleum. Therefore the focus of criticism is on the finiteness of this ressource. The public discussion about the problems of fossil energy sources makes it easy to understand that a basic material so limited in its availability cannot fulfill even the most basic requirements for sustainability.

A less known fact is that, at the end of their life cycle, all petrochemical products basically have the same impact as the petroleum burnt to generate energy. In the end the carbon contained in petrochemicals becomes the greenhouse gas carbon dioxide that cannot reenter the natural cycle and thus becomes a steadily increasing threat to the atmosphere.

However, petrochemistry holds another sustainability problem that even many chemists are not aware of. The chemical components of petroleum, mostly so-called hydrocarbons, are extremely inappropriate for the use as starting point for chemical processes.

This seemingly paradox insight is mainly based on two facts: For one thing petrochemical hydrocarbons virtually have no usable chemical functionality, for another thing they are extremely slow to react and thus resist every simple chemical transformation into materials that dispose of such a usable functionality.

These two facts lead to the fatal finding that petroleum can only be made chemically usable by means of enormous technical and energetical efforts. Modern chemistry's methods to solve this problem strike the naïve observer as being rather rude: For a start, the petroleum molecules get nearly completely "cracked", a process that needs a high energy input.

The crack products, little hydrocarbon molecules of various grades, still lack usable chemical functionalities. Consequently, after having been arduously cracked, these products now have to be bound in bigger molecules to possibly produce "fine chemicals" with the desired function, e.g. colours, scents, cleaning, biocidal effect, fibres, foils, plastics etc.

Unfortunately, the cracked molecules are still very slow to react and do not form the desired compounds spontaneously and on their own. On the contrary, another big amount of energy has to be used to make these cracked molecules into bigger ones again. For this process, chemists use extremely reactive and therefore highly aggressive chemicals like chlorine or ozone whose high energy content, by the way, also is not natural but a result from massive energy enrichment.

Notwithstanding the scientific-technical ingeniousness involved, these methods are rather rude and, unfortunately, have a lot of unwanted side effects. The high number of by-broducts and the immense amount of waste can only partly and with high expenditures be converted into something useful.

This brief sketch of concomitant circumstances of today's petrochemistry shows that petrochemicals are the result of a radical, profound encroachment on the molecular identity and integrity of the original matters contained in the petroleum, a process accompanied by high energy consumption. Therefore, modern organic chemistry is characterised by an extreme "denaturation" of the petroleum that originally is a natural raw material but is lacking the crucial sustainability characteristic: It is not renewable.

To sum up, we can say that the central problem of petroleum as chemical raw material is its insufficient aptitude for this purpose; a more than strange fact given the predominance of petrochemistry. The matters contained in petroleum can only be brought into a form usable for everyday chemistry by radical chemical treatment, with a high energy input and a resulting strong molecular modification. Among the consequences of this strong modification are high energy consumption, vast amounts of waste, and also the formation of materials alien to nature with hardly foreseeable, negative long-term effects on ecosystems.

The rediscovery of natural raw materials

In recent years, the problems with petrochemistry mentioned above, as well as a growing awareness for sustainability in chemistry, have led to a brilliant rediscovery of natural raw materials, especially renewable ones, as basis for a sustainable, future-oriented supply of everyday chemical products.

This subject is neither ideologically motivated nor nostalgic or just fashionable. It is rather a fundamental new alignment of the use of materials, and the committed research and educational work of AURO and its founders has contributed a lot. After an initial phase of ignorance and direct hostilities, a chemistry based on renewable raw materials has become a central subject in sustainability research and the number of such products is steadily growing.

Natural materials of vegetable origin as the basis of chemistry solve a whole raft of the problems that are connected to petrochemistry:

- Natural materials are renewable and thus allow the use without limitations in time.
- They emerge and decay in a perfect circle of materials and thus do not lead to waste or persistance problems.
- Their synthesis within the plant is powered by the sun and does not use up fossil or nuclear energy.
- The decentralised origin of natural materials in all parts of the world avoids the negative local concentrations the traditionally very centralised conventional chemical plants are known for.
- No dangerous co-reactants are needed for their synthesis, no dangerous or hardly degradable waste remains.
- In the wake of biodiversity with its abundance of chemical forms there follows the formation of a vast variety of basic materials of vegetal origin.
- Photosynthesis already cares for a very high energetic and structural level of basic materials of vegetable origin.
- Finally, these materials have a rich and diverse chemical functionality which, combined with the diversity of materials available, renders them usable immediately or after only little modification.

Many of these advantages are also valid for mineral basic materials of a modern chemistry. They are not per se renewable but many of them can also be used in everyday products without profound chemical change.

Natural materials and the conflicting priorities of refinement and denaturation

One of the key factors for the role chemical materials of plant origin will play in the future lies in the vast variety of the global flora. Other than the rather uniform petroleum, plant materials offer chemists and technicians a complete cosmos of chemical attributes and functions to be specifically used in everyday products but also in downright “bio high-tech products”, e.g. high-strength, lightweight materials with vegetable fibre reinforcement.

This maximum choice of materials also largely allows to abandon profound changes in the chemical structure of the vegetable base materials. As a rule, a base material with the attributes needed for a desired function can be found among the countless plant materials and be used directly after preparatory processes like separation, destillation or extraction.

However, this theoretically endless supply is sometimes limited by the real availability or the price of a plant-based material: The ideal material may be available but in momentarily very small quantities and, as a result, at prices that would render any finished product nonmarketable.

In cases like these it can make sense to use a natural raw material with a better availability and gently modify its chemical basic structure in a way that guarantees the required attributes and, at the same time, a reasonable price.

Of course, for modifications like these, a fundamental imperative of minimization has to apply. The principles of “gentle chemistry” demand that the level of interference, the energy input, the toxicity of chemicals used, as well as resulting byproducts and waste are all held at the lowest possible level.

Moreover, there has to be a favourable relation between the degree of modification and the sustainability effect. Ecologically, it can make sense to use a small amount of a strongly modified natural material if this leads to a big advantage with regard to sustainabilty (e.g. the complete abandonment of solvents) or if this enables, in the first place, the use of big amounts of plant materials not modified at all or only slightly modified (e.g. small amounts of mineral drying agents in paints based on plant oils).

Therefore, a choice of raw materials in compliance with sustainability factors does not follow black and white schemes but thoroughly balances all ecological and technological circumstances in order to optimise sustainability effects. The AURO Woodstain No. 160 is a particularly good example for the efficieny of this process of optimisation: Here we have a product with an unmatched technological quality (Test winner), solvent-free and produced on the basis of pure vegetable binders.

Below you will find a tabular survey showing the different levels of gradual modification (or denaturation). The food comparison was chosen for a better understanding of this graduation.

Levels of denaturation of paint raw materials, compared to food materials			
	Levels of denaturation from 1 (pure natural) to 8 (completely alien to nature)	**Examples from the field of paints**	**Similar denaturation level in the field of foods**
1	Pure natural product, unchanged by man	Spring water	Wild fruit
2	Pure natural product, harvested by man	Dammar resin	Corn
3	Natural product, only physically processed	Colophony resin	Wheat flour
4	Chemically modified natural product with a largely preserved molecular structure	Soap from vegetable oil	Baked bread
5	Chemically modified natural product with a significantly changed molecular structure	Alkyd resins	Polyglycerol ester
6	Synthetic material with a molecular structure "identical to nature"	Synthetic alizarin	"Nature identical" flavour
7	Synthetic material with a molecular structure similar to nature	Permethrin	PHB ester
8	Synthetic material with a molecular structure extremely alien to nature	Isoaliphates	Saccharine (sweetener)

In the production of food, as well as in paint manufacture, the “pyramid effect” should apply: Daily food, just like everyday chemical products like paint, should have a broad base of natural materials that are only slightly modified or, even better, not changed at all. Materials with a higher degree of modification should play a minor role. Preferably, materials heavily modified should not be used at all. So the choice of materials does not follow an “all or nothing” scheme but demands a balanced judgement and use of the given graduations.

Conclusion

A classification of the sustainability value of food as well as everyday chemical products can be defined along the lines of their “degree of modification”. Every modification, i.e. the physical and, particularly, the chemical change, of the natural state of materials leads to a “denaturation” that aggravates the reintegration of the material into the natural cycle.

Within this gradation, a mere physical process (grinding, extraction) constitutes a minor effect. The degree of denaturation rises with advancing physical processes, continuing with simple chemical processes, and up to materials completely alien to nature that can only be produced by extensive chemical manipulations and numerous successive steps of synthesis. The result shows no chemical resemblance to the original material.

Natural materials, and especially plant materials, are well-provided with a high chemical functionality and usability and thus can often be used without radical encroachment on their chemical identity. The enormous abundance of plants and minerals with completely different material characteristics allows to choose the material perfectly adapted to its particular purpose and thus avoid radical modifications.

AURO’s main principle of material use is to encroach as little as possible on the molucular integrity of raw materials, e.g. cold pressing of linseed oil, tapping of dammar resin, destillation of orange oil. If a chemical modification is necessary to adjust the function of a material, its molecular structure will be maintained as far as possible, e.g. soaps made of plant oils or beeswax, glycerol resin ester boiling from oils and resins, burning of earth colours.

Stronger modifications will only be allowed where little amounts of modified natural materials ensure an immense amelioration of overall sustainability factors (e.g. plant oil emulsifiers as amino soaps for completely solvent-free paints and stains) or where big amounts of little or not at all modified natural materials become usable in the first place, e.g. cobalt octoate as dryer for the hundredfold amount of linseed oil instead of acrylic binders made of 100% petrochemicals.