A winning concept of future eco-friendly flame retardants

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Inflammable materials and fire accidents

We are surrounded with various inflammabel materials

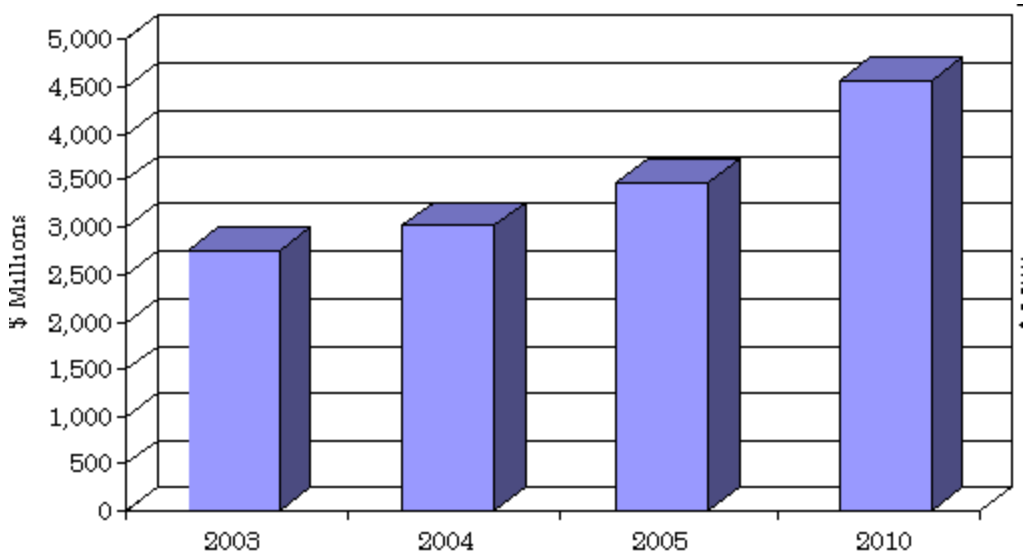
Inflammable materials and fire accidents

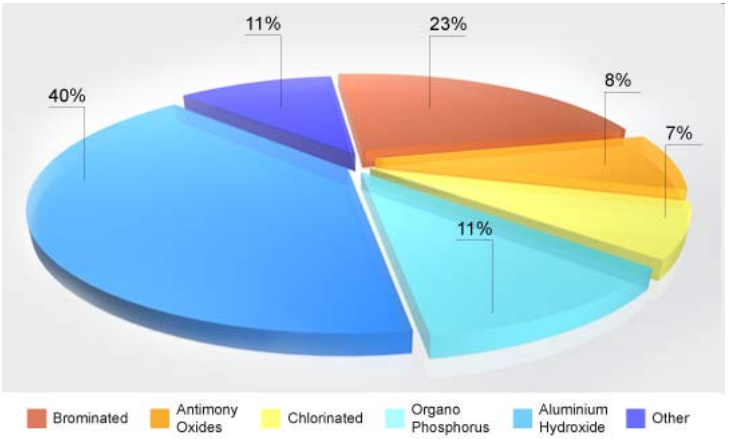
In Europe each year
- 4,000 deaths
- 80,000 injured

Mostly children under 5 and elderly.

Flame retardants of today – Rising levels of brominated flame retardants a concern?

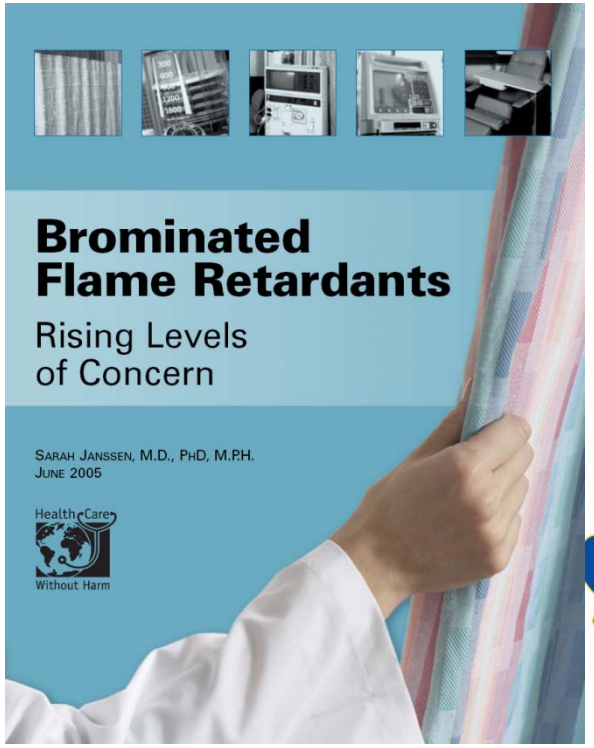
- Flame retardants are used to reduce fire risks in all sorts of materials such as plastics, wood, textiles, paper, etc that are daily surrounding us. The type of flame retardant used depends on the material and on the degree of fire safety required for the application.

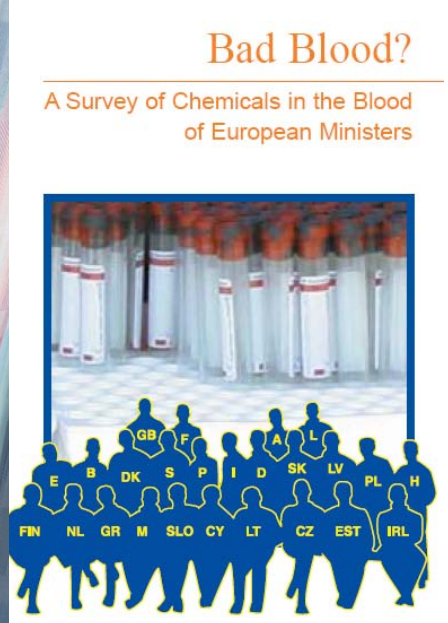


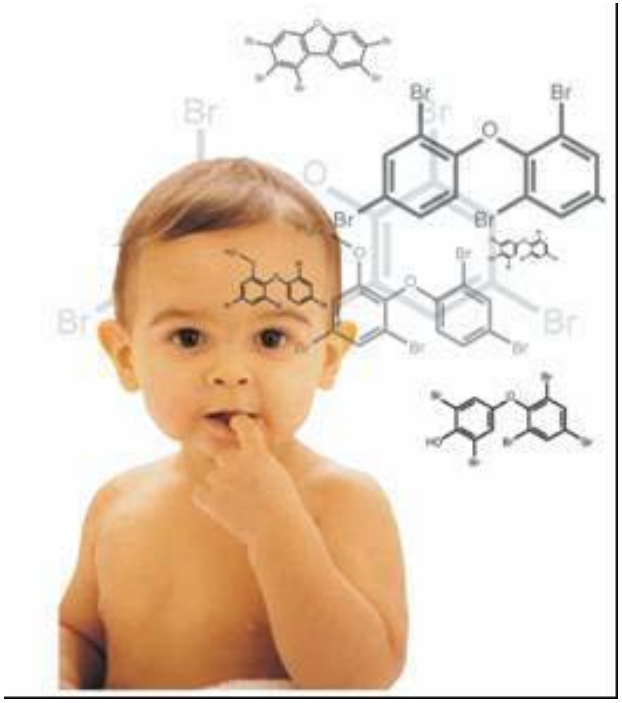


The flame retardant market is growing

Flame retardants of today – Rising levels of brominated flame retardants a concern?







"The pressure on brominated FRs should last as long as these chemicals are found in humans, animals and in the nature"

Flame retardants of today – Rising levels of brominated flame retardants a concern?

The Helsinki Commission, or HELCOM, works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden.
HELCOM is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" - more usually known as the Helsinki Convention.

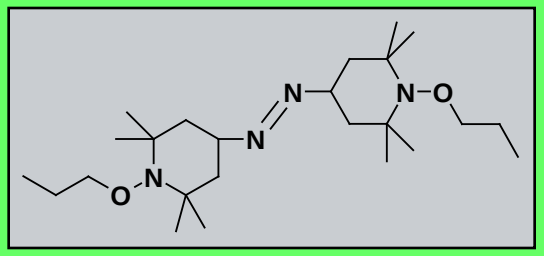
HELCOM substances / substance groups of specific concern to the Baltic Sea

(Baltic Sea Action Plan, HELCOM 2007)

Substances
1. Dioxins (PCDD), furans (PCDF) and dioxin-like polychlorinated biphenyls (PCBs)
2. Tributyltin compounds (TBT), triphenyltin compounds (TPhT)
3. Pentabromoduphenyl ether (pentaBDE), octabromodiphenyl ether (octaBDE), decabro modiphenyl ether (decaBDE)
4. Perfluorooctane sulfonate (PFOS), Perfluorooctanoic acid (PFOA)
5. Hexabromocyclododecane (HBCDD)
6. Nonylphenols (NP), nonyphenol ethoxylates (NPE)
7. Octyphenols (OP), octyphenol ethoxylates (OPE)
8. Short-chain chlorinated paraffins (SCCP), medium-chain chlorinated paraffins (MCCP)
9. Endosulfan
10. Mercury
11. Cadmium

Flame retardants of today – Rising levels of brominated flame retardants a concern?

NEW halogen free flame retardant



Aubert, M.; Wilen, C-E; Pfaendner, R; Kniesel, S; Hoppe, H; Roth, M. Bis(1-propyloxy-2,2,6,6-tetramethylpiperidin-4-yl)-diazene *Polymer Degradation and Stability* (2011), 96(3), 328-333.

- **Effective at very low concentrations**
- **First radical generator to pass UL94 VTM2 alone**
- **Provides both flame retardancy and light stability**
- **Good color and product form**
- **Excellent interaction with other flame retardant systems such as brominated flame retardants and ATH**

A winning concept of eco-friendly FRs - Looking for partners & experts for tasks 5 to 9

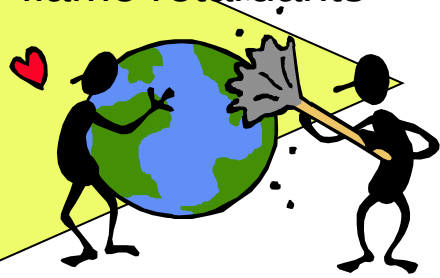
Design & synthesis of eco-friendly flame retardants

Evaluation of efficacy & properties

End-use market sectors and life-cycle analysis

Future eco-friendly flame retardants

1 2 3 4 5 6 7 8 9



Plastic formulations, applications and products

Assessing of environmental effects

Health & risk assessment

1. Synthesis and design of new eco-friendly flame retardants
- Design, development and synthesis of new halogen-free flame retardants
- Developing new chemistries and multifunctional flame retardants
- Characterization of chemical and physical properties of flame retardants
- Scale-up of flame retardant candidates in multi-gram scale

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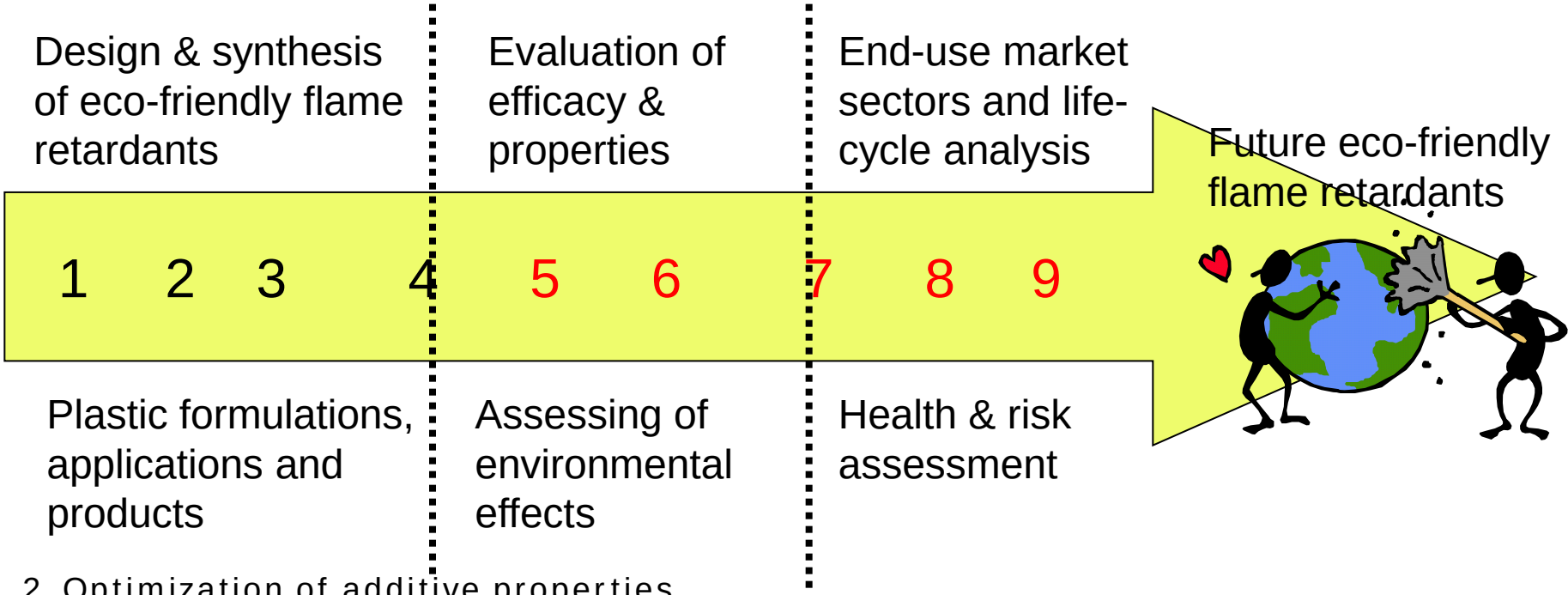

2. Optimization of additive properties

- Color, volatility, physical state (e.g. particle size, suppression of dust generation, melting temperature, etc), molecular weight and decomposition temperature
- Increasing maximum processing temperature
- Solubility, compatibility and migration tendency
- Usability and handling of flame retardant (SDS)

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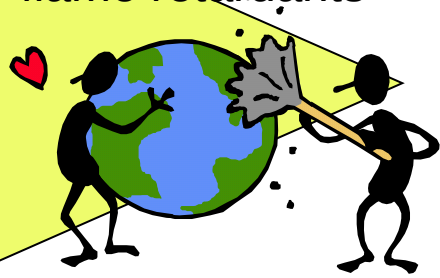

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Plastic formulations, applications and products

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3. Plastic formulations, applications and products
- Polymer processing and admixing of flame retardants
- Preparation of masterbatches and end use products

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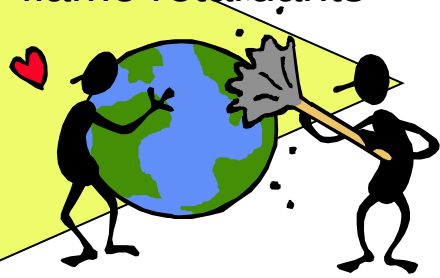

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4. Assessing of flame retardant performance, testing and mechanisms of action

- Fire testing (UL 94, DIN 4102 B, LOI, cone calorimeter, etc)) (smoke generation, burning dripping, heat flux, CO2/CO ratio, etc.)
- Use and interpretation of flame retardant test results
- Investigations of synergistic or antagonistic effects with existing flame retardant families
- Interactions with other additives/fillers
- Testing of long term performance

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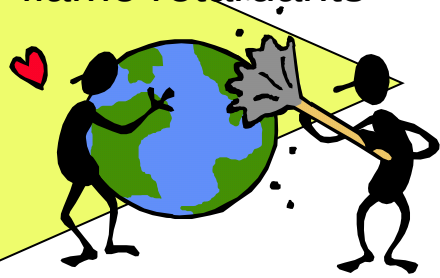

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5. Health and risk assessment
- HSE check for flame retarded products
- Effects to organisms and ecosystem
- Biochemical and chemical transformation processes
- Toxicity of metabolites and transformation product
- Model predictions for the fate of chemicals

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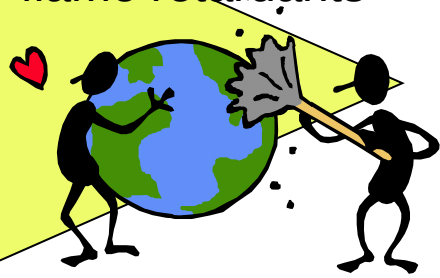

6. Combustion chemistry
- Polymer specific fire performance
- Single step pyrolysis (polymer to volatile products)
- Oxidative degradation of various polymers
- Propagation of fire

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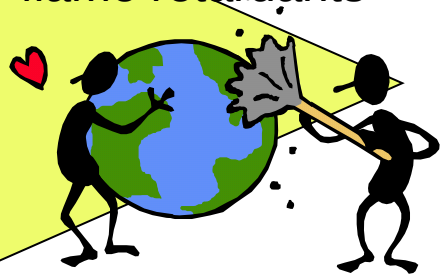

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7. Computer modeling of flame retardants chemical structures

- Molecular modeling and creation of molecular library
- Accurate prediction of thermal and electronic properties of novel radical generators
- Quantitative structure-based modeling applied to characterization and prediction of chemical toxicity
- Quantitative structure-activity relationships (QSARs)

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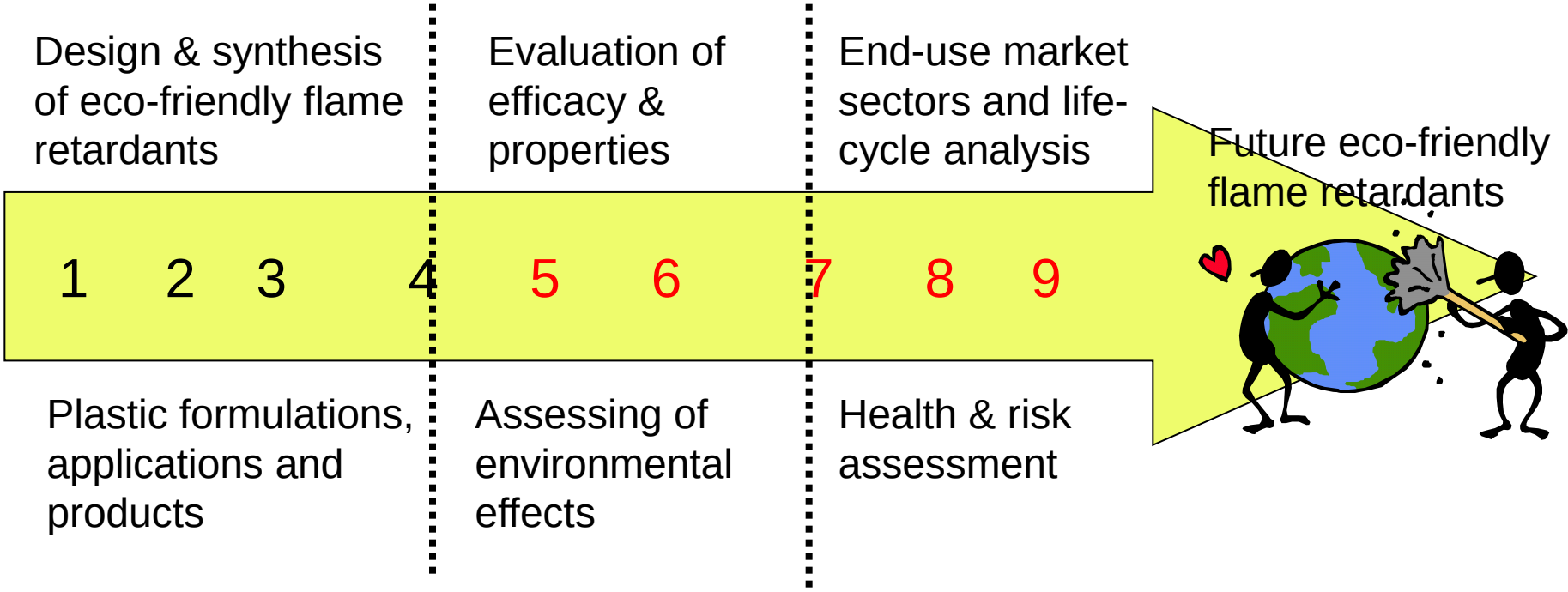

8. Life cycle analysis (LCA)
   - Product's life from-cradle-to-grave
   - Environmental concerns
   - Regulatory matters (REACH)
   - End user requirements
   - Recycling and end of life

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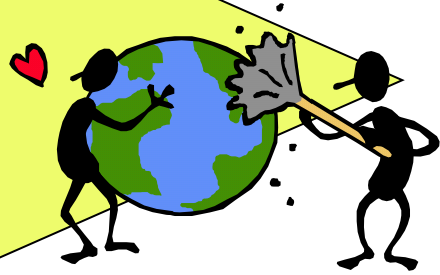

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9. Flame retardant markets and consultation of industrial experts
- Customer interviews and identification of product segments
- Opportunity assessment, business and market plans
- Bench marking and assessment of competitive advantages
- Assessment of freedom to operate and intellectual property rights (IPR)

References

- **a)** Nicolas R, Wilen C-E, Roth M, Pfaendner R, King R. Azoalkanes: a novel class of flame retardants. *Macromolecular Rapid Communications*, *27*(12), 976-981, **2006**. **b)** Aubert M, Roth M, Pfaendner R, Wilen C-E. Azoalkanes: a novel class of additives for cross-linking and controlled degradation of polyolefins. *Macromolecular Materials and Engineering*, *292*(6), 707-714, **2007**. **c)** Aubert M, Nicolas R, Pawelec W, Wilen C-E, Roth M, Pfaendner R. Azoalkanes—novel flame retardants and their structure–property relationship. *Polymers for Advanced Technologies*, (in press) DOI: 10.1002/pat.1642. **d)** Nicolas R, Wilen C-E. PCT Int. Appl. (**2005**), *WO 2005030852 A2 20050407*. **e)** Roth M, Pfaendner R, Wilen C-E, Nicolas R. PCT Int. Appl. (**2006**), WO 2006106059.
- **a)** Aubert, Melanie; Wilen, Carl-Eric; Pfaendner, Rudolf; Kniesel, Simon; Hoppe, Holger; Roth, Michael. Bis(1-propyloxy-2,2,6,6-tetramethylpiperidin-4-yl)-diazene - An innovative multifunctional radical generator providing flame retardancy to polypropylene even after extended artificial weathering. *Polymer Degradation and Stability* (**2011**), 96(3), 328-333. **b)** Roth M, Pfaendner R, Wilen C-E, Aubert M. PCT Int. Appl. (**2008**) WO 2008/101845.
- Pictures taken mainly from (or internet):
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