pinfa
Phosphorus, Inorganic & Nitrogen Flame Retardants Association

Your newsletter for non-halogen fire safety solutions
No. 77 March 2017

Upcoming events

- 25-26 April, Pittsburgh PA, USA , **AMI Fire Retardants in Plastics 2017**
- 26-28 Sept., Dearborn, near Detroit, USA, **pinfa NA workshop**: **Fire Safety Requirements in Automotive Design**. pinfa NA's 5th annual workshop, co-organised with SAMPE (Society for the Advancement of Material and Process Engineering) will assess how trends in automobile design will impact flame retardant selections, with car manufacturers and suppliers, regulatory and materials technology experts. Info: Timothy.Reilly@clariant.com

For full events listing, see www.pinfa.eu

pinfa's General Assembly, 23rd November 2016, identified key challenges facing flame retardants: 'chemophobia', a generalised negative image of chemicals used as flame retardants for fire safety, concerns about smoke toxicity and the move towards the 'circular economy'. PIN flame retardants need to combine contributing to fire safety and to saving lives and property with higher levels of health and environmental safety, and also to be compatible with lower smoke toxicity and with plastics recycling. The General Assembly elected a new Board in continuity of pinfa's action to date: Michael Klimes, Nabeltec, who has chaired pinfa since its launch in 2009, is replaced as Chairperson by Adrian Beard, Clariant. Pinfa now has two Vice-Presidents, Michael Klimes, who continues his involvement, and Thomas Futterer of Budenheim. Vincente Mans of Budenheim is delegated to represent pinfa in stakeholder contacts. pinfa today has 25 members and associate members. The meeting discussed pinfa's actions including work on smoke toxicity, dialogue with policy makers, fire fighters and NGOs and exploration of flame retardants' uses and utility, recycling of PIN flame retardant polymers, cooperation with pinfa North America, and workshops in Italy, Asia, and elsewhere. Communications are key to pinfa's action, and the General Assembly welcomed the positive feedback from the pinfa Newsletter questionnaire (see below).*

** chemophobia is a fear of all chemicals, without understanding distinguishing between different chemicals (both man-made and natural) with different properties. It can be fuelled by inaccurate marketing campaigns. A recent example of using chemophobia for marketing purposes can be seen with French supermarket chain SuperU advertising where chemicals become cartoon monsters http://tbtc.fr/magasins-u-caverne/#sthash.pqImdYhz.BDh0h8LH.dpbs.*

The new pinfa executive team (from the left): Vincent Mans, Thomas Futterer, Adrian Beard, Philippe Salémis and Michael Klimes

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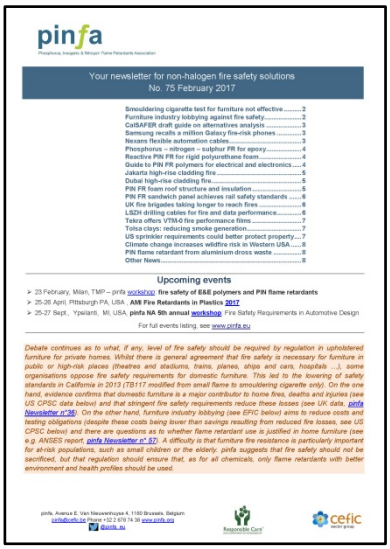
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No. 75 February 2017

Upcoming events

Positive reader opinion of the pinfa Newsletter

The pinfa Newsletter is emailed to over 4 500 people. For recent Newsletters, over 600 are indicated by the email system to have opened the email (this may underestimate, as not all email systems return this information). The questionnaire sent out last autumn registered a relatively low response (72 returns). This possibly not representative sample expressed a positive opinion of the Newsletter (often useful for 64%) and of its redesign in 2016 (64%) Most of the respondents were international, rather than European. Many comments point to the usefulness of information about updates on products and applications. 89% of respondents identify information on "New PIN FR products and applications" as of most interest, followed by 79% for "R&D into new PIN FR solutions". Most people read the Newsletter as email on their computer (85%) but 20% download the PDF version. Several comments noted the value of pdf as an easy format to transfer. Three quarters of respondents sometimes forward the newsletter to other contacts.

pinfa Newsletter www.pinfa.eu

Consumers call for EU action on fire safety

The European association for the coordination of consumer representation in standardisation (ANEC) has called for a coordinated approach to fire safety in the EU: "*All consumers should benefit from common essential safety requirements across Europe, with risk assessment ensuring that measures are proportionate and appropriate*". ANEC has already for over five years been requesting consistent fire safety requirements in tourism accommodation across Europe – but without success. ANEC underlines that there is a need to address chemicals in products relevant to consumers, to enable coherence between sustainability objectives and building safety and requests "*a comprehensive discussion on how to avoid toxic flame retardants and to find safer substitutes is necessary, especially where safety cannot be ensured … by using materials which are inherently fireproof*".

ANEC "The EU needs a strategy on fire safety", 24 November 2016, ANEC-PR-2016-PRL-011
http://www.anec.eu/attachments/ANEC-PR-2016-PRL-011.pdf

Human cost of fires in Canada: 400 million €/year

Studies in Canada estimate the human cost of residential fires over 14 years (1998 – 2012) at 7.6 billion CAD (nearly 400 million €/year), including value of potential years of life lost (PYLL), fire victim patient treatment, rehabilitation, transport and property loss. Over these 14 years, more than 24 000 years of life potential were lost in Canada due to home fires. The authors note that most of Canada's home fire deaths are due to smoke inhalation. Costs of fire victim hospital treatment, based on over 1 000 cases in Ontario, was over 80 000 CAD (60 000 €) per patient

"High human cost of burns means $7.6 billion economic loss in Canada" 7 Nov. 2016 http://sunnybrook.ca/media/item.asp?page=38&i=1491 and "Healthcare costs of burn patients from homes without fire sprinklers", J. Burn Care Res 2015, 36(1°, 213-217, J. Banfield et al. http://dx.doi.org/10.1097/BCR.0000000000000194

Smoke alarms could have prevented 40% of fire deaths

144 non-intentional fires which led to deaths in Swedish homes were analysed, based on assessing the chain of events which led to the death: heat source, ignition of first object, fire growth and spread, evacuation initiated, final consequences. This suggests that sprinklers could have prevented death in 60-70% of cases and smoke alarms in only 37% of cases. Where the victim was a smoker with home care (home care is indicative of mobility difficulties) effectiveness was very considerably lower, (respectively 31% for sprinklers, 14% for smoke alarms). This shows the need for different prevention measures for different populations. In one fifth of cases studied, the victim could have evacuated but chose not to do so because they chose try to fight the fire, showing the importance of behaviour education. For the 144 cases studied, the authors estimate that flame resistant bedclothes would have prevented 24% of fatalities but would have prevented 50% of fatalities for smokers with home care. For the 144 cases, flame resistant upholstered furniture would have prevented 15% of fatalities, and flame resistant clothing 11%. In the cases in which fires which started in upholstered furniture, the most frequent cause was cigarettes, with also nearly one fifth being caused by electrical faults igniting the furniture.

"How could the fire fatalities have been prevented? An analysis of 144 cases during 2011–2014 in Sweden", M. Runefors, N. Johansson & P. van Hees, J. Fire Sciences, 2016, Vol. 34(6) 515–527 http://dx.doi.org/10.1177/0734904116667962

Eco Red Shield™ achieves Class A timber fire safety

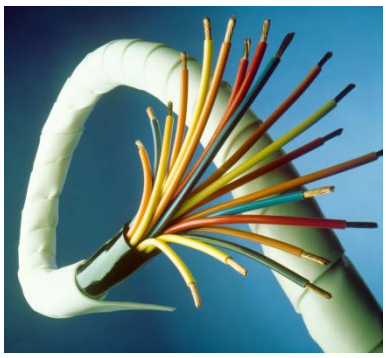
Eco Building Products, Inc., California, has achieved fire test UL723/ASTM E-84 (flame spread index < 25, progression < 10.5 feet, in an extended 20 minute test time) for Eastern Spruce (SPF) and Douglas Fir treated with the company's PIN (phosphorus, inorganic, nitrogen) Eco Red Shield ™ coating. The treated timber can thus be used for roof and floor structural elements in buildings, conform to fire safety requirements. The coating also protects against wood rot, mold and termite damage, contributing to making lumber a safe and sustainable building material. It shows very low emissions (mostly non quantifiable levels BQL) of volatile organic compounds VOCs and low formaldehyde emissions (ASTM D5116), meeting California 01350 for indoor air emissions.

Eco Red Shield fire test video and "Eco Building Products, Inc. Announces New Class "A" Fire Treated Lumber Species. Eco's Proprietary Topical Coating Eco Red Shield FT™ Expands to Include Eastern Spruce (SPF) Dimensional Lumber" 26th April 2016. http://www.marketwired.com/press-release/eco-building-products-inc-announces-new-class-a-fire-treated-lumber-species-otc-pink-ecob-2118262.htm

Identification of VOCs in house fire smoke

A house due for demolition was used to carry out 13 room fire tests: 2 with kitchen cooking oil, 7 with a burning sofa and 4 in furnished rooms (2 kitchen, 2 sofa in lounge). The sofa was flame retarded to UK Furniture Fire Safety Regulations standards. Qualitative analysis of (semi) volatile organic carbon (VOC) chemicals was carried out in fire gases, aerosol soot in these gases and in condensed particles, during fire start, development and after combustion. Quantitative measurements were not made, only presence or not of each chemical. Benzo(a)pyrene was detected in both gases and post-combustion soot in nearly all burns, as were another 21 IARC classified (cancer risk) compounds, in particular anthracene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene, fluoranthene, naphthalene, phenanthrene and pyrene – as can be expected in any carbon-rich, under-ventilated fire. 10 organic phosphorus compounds, flame retardants or FR breakdown compounds, were analysed. One or more of these was detected in either fire gases or condensed soot in only 7 out of 10 of the burns involving sofas, but not in post-combustion soot. Only two FRs TCPP* and TBEP* were detected in smoke or soot in more than 3/10 burns. Because results are only qualitative (presence or not) with no quantification, no conclusions can be drawn concerning exposure or risk.

"Release of volatile and semi-volatile toxicants during house fires", F. Hewitt et al., Chemosphere (2017) http://dx.doi.org/10.1016/j.chemosphere.2016.12.079



Improving PIN FR polyethylene compounds for cables

Dow Corning have launched a new polyethylene MB25-502 Masterbatch for production of non-halogen flame retardant cables, wires and jacketing. The inclusion of specific silicone additives ensures improved processability for extrusion, by reducing screw torque without the need for processing additives, even at up to 70% loadings of mineral PIN flame retardants and fillers, whilst ensuring cost-effectiveness by using polyethylene (PE) base. The masterbatch, supplied as free-flowing pellets, is compatible with low density PE (LDPE), linear low density PE (LLDPE) and cross-linked PE (XLPE). See also pinfa Newsletters n°s 65 and 71.

"New Dow Corning® MB25-502 Masterbatch Delivers Best-in-Class Processability for Polyethylene Wire and Cable Insulation and Jacketing", 15/12/2016
http://www.dowcorning.com/content/news/mb-25-502-best-processability.aspx

Non-migrating PIN FR for polycarbonate

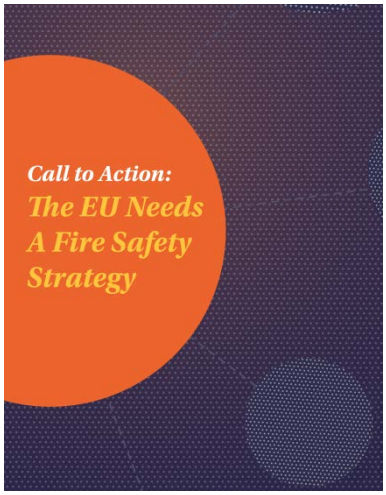
A US patent assigned to PolyOne, Ohio, is published for a phosphorus-mineral flame retardant for polycarbonate, formed by reacting in situ (within the polymer) a phosphorus compound (alkyl-functional phenoxyphosphazene) and a silicon compound (hydride-functional siloxane). The patent states as its achieved objectives of non-halogenated, UL94-V0 fire performance (3.2mm) in polycarbonates, non-dripping and using no solvent in production. The in-situ reaction results in an interpenetrating network (IPN) PIN FR molecular structure within the final polycarbonate polymer, so ensuring that the FR will not migrate out of the polymer into the environment.

US patent 2016/0272812, published 22 September 2016, C. Zhou, R. Avakian, Polyone Corporation "Phosphazene flame retardant polycarbonate compounds"
http://www.freepatentsonline.net/20160272812.pdf

Toxicity of smoke in car fire

A full scale fire test was carried out in a 1989-built 4-seater car, from which fuel and lubricants had been removed. The car was ignited by placing a burning pan of 12l of fuel by the front right tyre. After 2 minutes, the front of the car was completely engulfed in flames. After 5 minutes, the temperature on a front seat dummy passenger had reached 80°C and smoke toxicity in the passenger compartment had reached hazardous levels sufficient to prevent escape, reaching lethal levels before 6 minutes. The principal toxic gases in smoke were carbon monoxide, nitric oxide, hydrogen cyanide. Carbon monoxide was emitted in much larger quantities than other toxic gases (except carbon dioxide), but levels of nitric oxide reached lethal concentrations at 5.4 minutes, carbon monoxide at 5.9 minutes and hydrogen cyanide at 6 minutes. The authors conclude that escape time is only a few minutes in case of a fire starting in a car, e.g. after an accident. They note that modern cars have significantly higher contents of flammable polymers than this 1989 model and that a fire starting in the car interior would become even more rapidly critical for occupants.

"Investigation of smoke gases and temperatures during car fire – large-scale and small-scale tests and numerical investigations", S. Krüger, A. Hofmann et al., Fire & Materials 40, 785-799, 2016 http://dx.doi.org/10.1002/fam.2342



Call for an EU fire safety strategy

Fifteen industry, consumer and fire fighter organisations have published a policy paper calling for "*a fire safety strategy for Europe*". The paper centres on building fire safety. 5 000 fire incidents occur every day in the EU, leading to around 70 000 hospitalisations, and costing around 1% of GDP. The paper also points to the dangers of smoke and soot from accidental fires, both cancer risks for fire fighters, and particle emissions*. The increasing use of combustible materials in furniture and other building content is underlined as leading to fires in buildings which develop faster, aggravated by energy efficient (highly insulated, air-tight) buildings and use of combustible materials in the building itself, with sustainability objectives playing a major role in these changes in buildings. The paper calls on the European Commission to "set up an expert group on fire safety ensuring participation of a wide array of stakeholders … to map the issues, identify potential solutions, and draft a roadmap to achieve them." Coherence of data collection, statistics and sharing of best practice are considered important. The paper calls for coordinated action across European Commission services (DGGROW, DG ENVI, DG JUST, DG ENER, Civil Protection, CNECT, Consumers, EMPL, education EAC and SANTE)

*"Call to Action: The EU Needs A Fire Safety Strategy", November 2016, 26 pages, FireSafeEurope and other organisation http://firesafeeurope.eu/campaign-the-big-picture/ and http://firesafeeurope.eu/wp-content/uploads/2016/12/Fire-Safe-Paper-Final-web.pdf * a 2002 SP Sweden study is cited as indicating that building fires generate particle emissions equivalent to commercial road transport.*

Mineral PIN FR for lithium ion battery cathodes

"Runaway" heat release in lithium ion batteries usually starts with loss of integrity of the solid-electrolyte interface (SEI). The electrolyte then contacts the anode, reacting and generating heat, leading to electrolyte decomposition, further reaction, and thus to cathode decomposition. Cathode decomposition is critical, because it releases

oxygen and so can cause fire or explosion. Fire protection of both electrolyte and cathode are therefore necessary to improve lithium ion battery safety. In these studies, the mineral PIN flame retardant boehmite [aluminium oxide hydroxide AlO(OH)] was tested for lithium-iron-phosphate ($LiFePO_4$) cathodes. Fire risk was reduced by up to 50% (reduction in self extinguishment time), without deterioration of cathode electrochemical performance, by addition of 15% of microparticulate boehmite encapsulated in poly(urea formaldehyde). Non-encapsulated boehmite or larger particles were less effective.

"Encapsulation of flame retardants for application in lithium-ion batteries", P.-H. Huang et al., J. Power Sources 338 (2017) 82e90 http://dx.doi.org/10.1016/j.jpowsour.2016.11.026 and "Boehmite-based Microcapsules as Flame-retardants for Lithium-ion Batteries", P.-H. Huang et al., Electrochimica Acta 2017 http://dx.doi.org/doi:10.1016/j.electacta.2017.01.094

Phosphorus FR encapsulation for lithium ion batteries

Researchers at Stanford University, California, have developed a "smart" phosphorus flame retardant solution for lithium ion batteries. The phosphorus flame retardant is encapsulated in electrospun microfibres, held in the electrolyte between the cathode and anode. The microfibers have a polymer shell (PVDF-HFP poly(vinylidene fluoride – hexafluoroporpylene) is proposed) within which is a phosphorus flame retardant (TPP triphenyl phosphate is proposed). This avoids the need to dissolve the flame retardant in the electrolyte, which tends to deteriorate battery electrical performance. The flame retardant is released in case of battery overheating, because the polymer microfibre shell melts (at around 160°C). Tests show that electrolyte flames can be extinguished in less than half a second.

"Fire-fighting lithium–ion battery doesn't compromise on performance", Chemistry World 17th January 2017 https://www.chemistryworld.com/news/fire-fighting-lithiumion-battery-doesnt-compromise-on-performance/2500264.article and "Electrospun core-shell microfiber separator with thermal-triggered flame-retardant properties for lithium-ion batteries", K. Liu et al., Sci. Adv. 2017 - 3: e1601978 http://advances.sciencemag.org/content/3/1/e1601978

Biochar – wool – polypropylene – PIN FR composite

Biochars can be highly porous (high surface area), giving mechanical performance and compatibility advantages in polymers (infiltration of pores by polymer), and are fire resistant. Low grade wool is a widely available waste fibre with good charring ability. Both can therefore be attractive renewable components for polymer composites. In this paper, a composite with 15% pine wood sawdust biochar (pyrolysis at 500°C followed by activation at 900°C), 10% wool fibres and 15% ammonium polyphosphate (PIN flame retardant) in polypropylene was tested for fire performance and mechanical properties. This composite showed fire performance with reduced peak heat release rate (PHRR), reduced smoke production and lower carbon monoxide emission, enhanced LOI (limiting oxygen index) and mechanical properties comparable to or better than pure polypropylene (flexural strength, tensile/flexural moduli).

"Development of waste based biochar/wool hybrid biocomposites: Flammability characteristics and mechanical properties", O. Das, Journal of Cleaner Production 2017 http://dx.doi.org/10.1016/j.jclepro.2016.12.155

New PIN FR polycarbonates for E&E applications

Polymer Technology and Services (PTS, Murfreesboro, Tennessee), a global flame-retardant engineering thermoplastic compounder, has introduced four new halogen-compliant polycarbonates for electrical and electronics applications. The new Tristar AR compounds achieve UL94-V2, B0 and V1 or 5VA and V0 depending on thickness and grade. Non-mains electrical equipment (hand held) generally requires UL94-V2 or UL94-V0, whereas mains equipment requires UL94-V0 and unattended mains equipment (e.g. electrical, telcommunications) require the more demanding UL94-5VA. The Tristar polycarbonate compounds combine these levels of fire safety performance with high material strength and flexibility for recycling and reuse. They are ULK certified 746R and 746H, meaning that they do not contain chlorinated or brominated substances conform to IEC 61249.

"Polymer Technology and Services expands Tristar range of flame-retardant polycarbonates", 12/12/2016 https://www.plasticstoday.com/materials/polymer-technology-and-services-expands-tristar-range-flame-retardant-polycarbonates/48969048747123

Working together for fire safety in France

Established in 1948, France's professional group for passive fire safety GTFI www.gtfi.org brings together a range of professionals and companies involved in fire safety, including manufacturers, distributers and installers of fire safety products and flame retardants. The group has elected a new President, Gaétan Fouilhoux of Rockwool France, producer of inherently non-flammable mineral fibre insulation materials. Mr Fouilhoux has 25 years' experience in the building sector, including with the French small-company builders federation (CAPEB). The other members of the newly elected Board of GTFI are Pierre Cardin, Thor France (pinfa member www.thor.com), Jean-Baptiste Aurel, Woodenha (timber treatment www.woodenha.com), Hubert Piriou, Promat (non flammable mineral fire-resistant materials https://promat.fr/), Pascal Brocault, Serpib (passive fire protection installation www.serpib.fr), Xavier Schmidt, ACH (fire stop solutions www.ach-fr.com) and Hervé Van Oost, Fibex (wood construction finishing www.fibex.fr).

GTFI Groupement Technique Français contre l'Incendie www.gtfi.org

Swiss TV programme promotes PIN FRs

Swiss TV channel SRF's "Einstein" programme, 22/9/16, presents the dangers of home fires, with five volunteer ladies seeing full-scale fires close-up, and presents state-of-the-art technologies to improve firefighting and fire safety – including PIN FRs developed by EMPA Switzerland. The programme opens by underlining that 40 people per year die in 20 000 home fires in Switzerland. Flashover in a small room is demonstrated and explained. Sabayachi Gaan, EMPA, shows that flammable materials (plastics and engineering polymers, foams, textiles, wood …) are everywhere in homes, trains, public spaces. The essential role of flame retardants in reducing fire dangers is presented, and the need for "environmentally friendly" FRs which will respect future regulation. Dr. Gaan presents organic P FRs developed by EMPA which are "non toxic and don't migrate out of materials". Tests show how these FRs prevent foams burning.

SRF Einstein "Es brennt, es brennt" (it's burning, it's burning), 22 September 2016, in German, whole programme 35 minutes and direct link to the 4 minute section on EMPA PIN FRs http://www.srf.ch/sendungen/einstein/es-brennt-es-brennt

ECHA sets out strategy for plastics additives chemicals

The European Chemical Agency (ECHA) has presented its strategy for plastics additives, stating as objectives by 2020 to improve chemical safety, identify all chemicals of Very High Concern (SVHC) and address all product lifecycle phases, including recycling. ECHA considers that this will require regular updating of chemical REACH dossiers (whereas 2/3 of 2008-submitted dossiers have not been updated) and less reliance of read-across. ECHA wishes to develop an inventory of plastics additives (based on PESTOOL), to map uses and applications (requiring supply chain communication), and to define criteria for determining exposure in product life and in waste (Cefic, DUCC and ECHA have signed a joint commitment to work on use map information. ECHA also suggest that more information on uses is needed in IUCLID. ECHA note that substances which are 'contained' in products are recognised to have low exposure potential (in particular, chemicals permanently embedded in polymer matrix).

ECHA presentation at Cefic Plastic Additives Sector Workshop, Brussels, 25 November 2016. "Communication is key to chemical safety: Cefic, ECHA and DUCC join forces", 6/10/2016 http://www.cefic.org/newsroom/More-news-from-2016/Communication-is-key-to-chemical-safety-Cefic-ECHA-and-DUCC-join-forces/

Other News

FRs around electronics dismantling sites: a study in China comparing 175 people (46 controls) living a few hundred metres from e-waste dismantling areas in Qingyuan showed elevated urine concentrations of two out of eight flame retardants metabolites analysed in urine (BCEP, DPHP). Four of the eight metabolites showed correlation to levels of 8-OHdG, a marker for DNA oxidative stress, but this does not prove cause to effect.

The eight FR metabolites analysed were: bis(2-chloroethyl) phosphate (BCEP), 102 bis(1-chloro-2-propyl) phosphate (BCIPP), bis(1,3-dichloro-2-propyl) phosphate (BDCIPP), 103 bis(2-butoxyethyl) phosphate (BBOEP), dibutyl phosphate (DBP), di-o-cresyl phosphate (DoCP), 104 di-p-cresyl phosphate (DpCP), and diphenyl phosphate (DPHP) ("Effect of E-waste Recycling on Urinary Metabolites of Organophosphate Flame Retardants and Plasticizers and Their Association with Oxidative Stress", Lu et al., Env. Sci & Technology 2017 http://dx.doi.org/10.1021/acs.est.6b05462

NGOs petition US EPA on FRs: US Environmental Protection Agency has acknowledged receipt of petitions under section 21 of TCSA from six environmental NGOs led by Earthjustice requesting hazard and exposure testing for tetrabromobisphenol A (TBBPA) and for three chlorinated phosphate esters TCEP, TDCPP and TCPP. In both cases the petitions suggest that further information is needed to determine these chemicals effects during the full life cycle.

Petition on chlorinated phosphate esters https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/support-document-chlorinated-phosphate-ester-cluster Petition on TBBPA https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/support-document-tetrabromobisphenol-tbbpa-section-21

EU Ecolabel criteria on floor coverings: the European Commission has published updated Flower Ecolabel criteria for wood, cork and bamboo based floor coverings. Whereas the previous 2009 criteria did not include any specific requirements regarding flame retardants (all chemicals subject to exclusion of certain R-Phrases), the new criteria include a blanket exclusion of all flame retardants "in the substances used in the manufacture" of EU Ecolabelled floor coverings. pinfa considers that this exclusion is not based on an assessment of whether flame retardants are needed in some floor coverings to ensure fire safety, nor of whether flame retardants are available to achieve this without health or environmental risks.

European Commission 2017/176 "establishing EU Ecolabel criteria for wood-, cork- and bamboo-based floor coverings" 25 January 2017 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32017D0176

Swedish Chemicals Agency studies sex toys: KEMI (the Swedish Chemicals Agency) has assessed 44 sex toys from 16 companies, especially soft plastic and electrical devices. The only restricted substance identified was short chain chlorinated paraffins in one product, possibly being used as a softener not as a flame retardant. A phthalate on the EU SVHC list, requiring notification, was found in three products intended for use outside the body. KEMI suggests that "*companies in other sectors can learn from the work of sex toy companies on chemical issues*". No analysis of levels of consumer exposure to these products is proposed.

"New test shows nearly all sex toys free of restricted chemicals", KEMI 23 January 2017, 16 page report in Swedish with English summary, including websites for products tested http://www.kemi.se/en/news-from-the-swedish-chemicals-agency/2017/new-test-shows-nearly-all-sex-toys-free-of-restricted-chemicals/

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For abbreviations see: www.pinfa.org