Sustainable Flame Retardant Development For Aircraft Cabin Safety

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Albemarle Corporation

POLYMER SOLUTIONS

Electronics, Construction, Packaging, Automotive, National Security

- Flame-retardants
- Antioxidants
- Curatives
- Stabilizers (Stannica LLC)

CATALYSTS

Energy, Transportation, Packaging

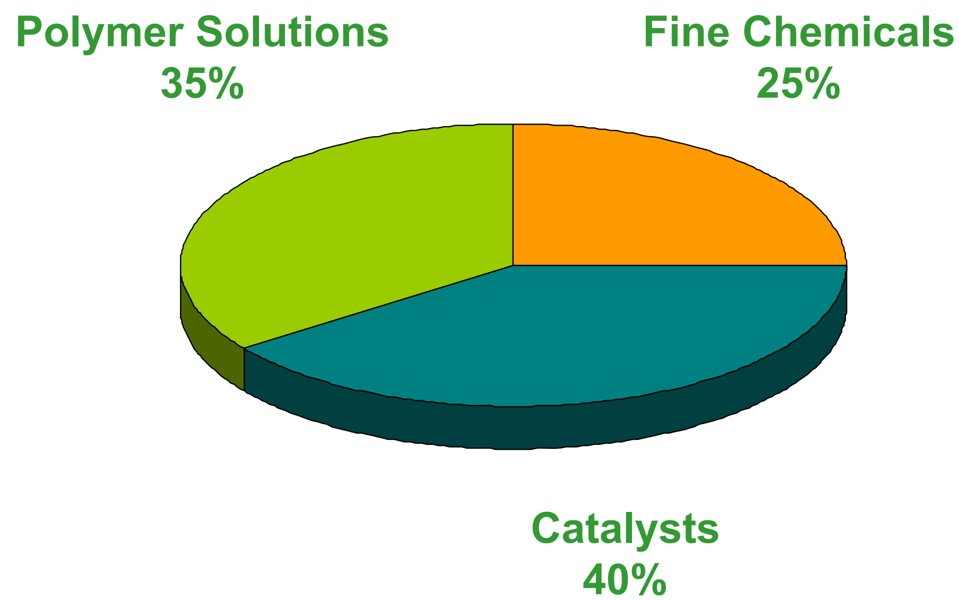
- FCC
- HPC
- Polyolefin and Chemical Catalysts
- Alternative Fuel Technologies

FINE CHEMICALS

Agrochemicals, Oilfield chemicals, Solvent cleaners, Paper chemicals, Biocides…

- Fine chemistry services
- Pharmaceuticals
- Bromine chemicals
- Other industrial specialties

2009 Net Sales - $2.0 billion



We have a broad, innovative Flame Retardant Portfolio

- Bromine
- Mineral
- Phosphorus

Balanced and Far Reaching

Consumer Electronics 16%

Const/Furnish 13%

Auto/Trans 8%

Household/PC 3%

Pharma/Nutr 6%

Ag Science 5 %

Energy/H2O 6%

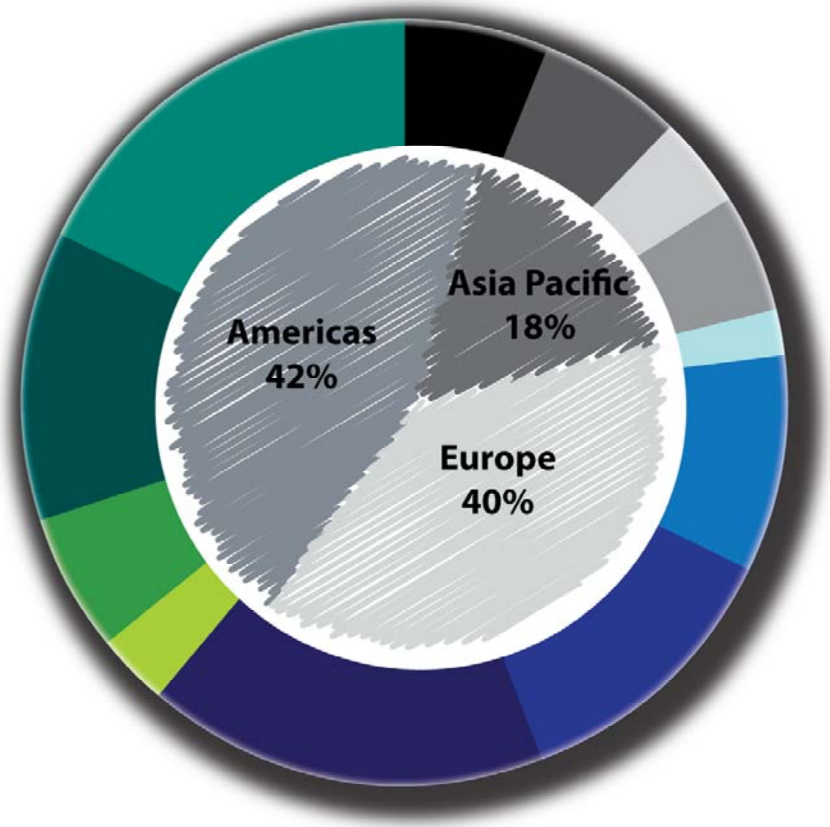
Chem Scv 7%

Fuel Quality 17%

Fuel Conversion 11%

Packaging 5%

Other 3%



% of 2008 Net Sales

Over 4,100 employees, in over 45 facilities, serving customers in more than 100 countries

Why are Flame Retardants Needed?

- Flame retardants are used to help:
  - Prevent ignition
  - Delay the spread of fires
  - Delay the time of flashover to enable people time to escape

Toronto, Canada, August 2, 2005: Flame retardants were credited with increasing escape times for all 309 passengers from this jet, which was ultimately completely consumed by fire.

Washington Post, Aug. 5, 2005

Fire Safety is a challenge, but is achievable in home, office, commercial, and transportation environments

Why are Flame Retardants Needed?

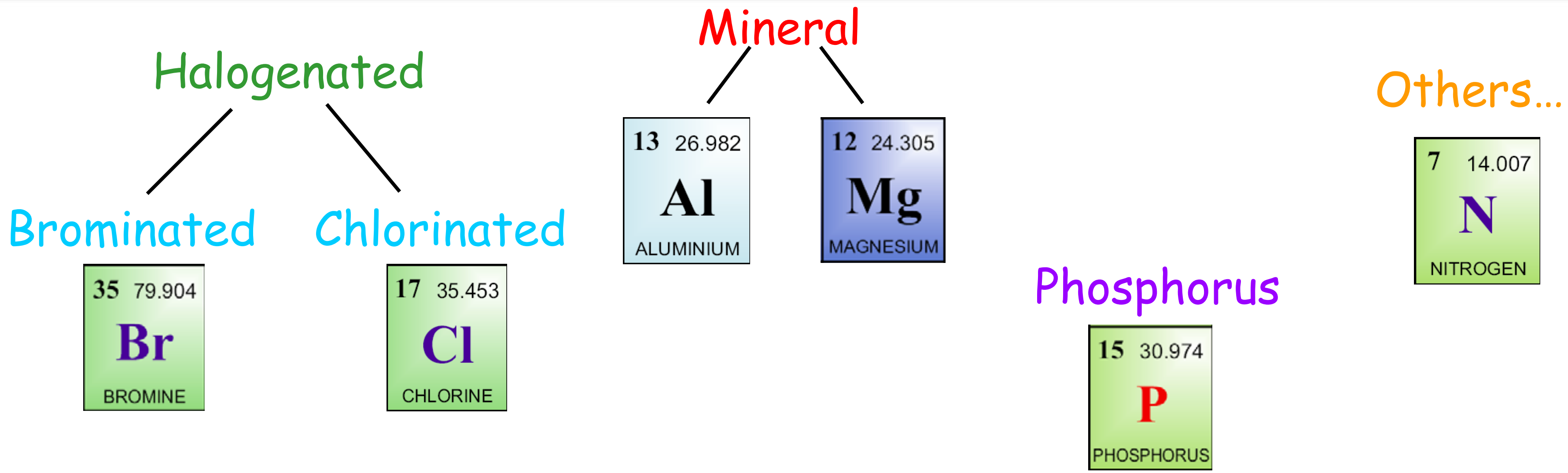
- Fire prevention is essential from a number of perspectives:
  - Protection of life
  - Protection of property and the environment
  - Prevention of immediate local pollution to air and water
  - Prevention of lesser-known long-term environmental effects

Combustion gases generated during fires (whether or not flame retardants are present) that contribute to acute toxicity include CO, HCN, HCl, and acrolein. Carbon monoxide is responsible for > 90% of all fire deaths *

The most important pollutants generated in fires are Polycyclic Aromatic Hydrocarbons (PAHs) and polyhalogenated dibenzodioxins and furans (PHDDs/PHDFs). Measurements have been made in large fires and have shown that the PAHs have an up to 500 times higher cancer risk than the PHDDs/PHDFs. PAHs are generated in all fires and many are carcinogenic compounds.*

* Troitzsch, J, “Fire Gas Toxicity and Pollutants in Fires – The Role of Flame Retardants,” FR2000 Conference, London, 8th-9th February 2000

Common Flame Retardant Classes



- Based on natural elements
- There are many different flame retardants in each of these classes
- Each individual flame retardant has it's own unique set of environmental, human health, physical, and chemical properties
- The distinct nature of individual flame retardants requires that each be treated on it's own merits

Common Flame Retardants

- Decabromodiphenyl ether – Deca-BDE
  - Electronics plastic parts, wire & cable, textile backcoating
- Tetrabromobisphenol A – TBBPA
  - Printed wiring boards (used in laminates – fully reacted with epoxy resins) and some plastic parts
- Hexabromocyclododecane – HBCD
  - Polystyrene foam and textile backcoating
- Other Br, P, or Cl FRs
  - Housings, PWB, connectors, wire & cable, adhesives, PU foam
- Mineral Flame Retardants
  - Wire & cable
- Antimony Trioxide - Sb_2O_3
  - Synergist typically used with additive BFRs

North American Regulator Activity

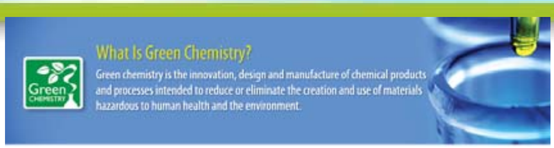
- State-by-state regulations - limited number of flame retardants
- TSCA Reform
- EPA
  - "Chemicals of Concern" Action List announced Dec 2009
    - Include phthalates, short-chain chlorinated paraffins, polybrominated diphenyl ethers (PBDEs), and perfluorinated chemicals, including PFOA
    - Process could lead to risk reductions actions under section 6 of TSCA
    - EPA also announced that three companies agreed to phase out Deca-BDE
    - Reinforcing the Deca-BDE phase-out – with requirements to ensure that any new uses of PBDEs are reviewed by EPA prior to returning to the market.
  - "Polybrominated Diphenyl Ethers (PBDEs) Project Plan"
  - High Production Volume (HPV) Challenge (~2200 HPV chemicals)
  - Design for Environment (DfE) program
    - Partnership with a broad range of stakeholders - Several have and are currently including flame retardants
    - Upcoming DfE will review Deca-BDE alternatives

DfE Program History

DfE Program Began	1992
Printed Wiring Board (PWB) Partnership	1995-2001
Screen Printing, Lithography, and Flexography Printing Partnerships	1994-2003
Garment and Textile Care Partnership	1996-2003
Safer Product Labeling Program	1997-Current
Best Practices for Auto Refinishing	1997-Current
LCD vs. CRT monitors LCA	1998-2001
Alternatives Assessments	
Lead-Free Solder for Printed Circuit Boards LCA	2002-2005
Furniture Flame Retardants Alternatives Assessment	2003-2006
Flame Retardants in Printed Circuit Boards	2007-Current
Phthalates, decaBDE, BPA	2010

U.S. Environmental Protection Agency

North American Regulator Activity



- CA – Green Chemistry
  - On June 23, it was announced that "The Green Chemistry Draft Regulation for Safer Consumer Products" was now available for review and comment (http://www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/gc_draft_regs.cfm)
  - The draft regulation specifies the processes for DTSC to scientifically and systematically identify and prioritize chemicals and consumer products, for manufacturers to conduct alternatives assessments, and for DTSC to impose regulatory responses for alternatives selected by manufacturers.
  - DTSC may revise the draft regulation based on comments received and will release the revised draft following the July 15 comment deadline. The formal Administrative Procedures Act (APA) rulemaking process will begin with the release of that draft.
- Canada - Implementation of Chemical Substances Plan

EU - RoHS Directive Recast & flame retardants – Review is Ongoing…

- **June 2, 2010 Vote**
  - European Parliament Environmental Committee voted to support amendments that require further evaluation instead of a ban on the use of certain organobrominated materials and PVC in EEE
  - MEPs voted in favor of an open scope (all EEE would be covered by the legislation, unless specifically excluded)
    - Exclusions recommended
      - Renewable energy generation
      - Certain large-scale installations and industrial tools
      - Materials for military purposes and vehicles
  - MEPs also called for a ban on nanosilver and carbon nanotubes and that other EEE material containing nanomaterials should be labelled (manf also supply safety data to the EC)
- **Next Steps - Amendments will now**
    - Be considered by the full plenary session of the European Parliament
    - Also has to be agreed on by the EU Council of Ministers to become law

EU – RoHS Recast & flame retardants

Recast Processes Timeline

Council of the Member States

← Regular RoHS & WEEE working group meetings →

Common position at the Council?

Final agreement?

Dec 2008 EC proposal	Nov 2009	Mar 2010	Apr 2010	June 2010	Oct 2010	End 2010	2011
European Parliament	Rapporteur → Rapporteur's draft report	Deadline for amendments → Final draft report	Debate in EP Environment committee	Environment committee on the report → Final Environment committee report	Plenay vote on the report → Final EU Parliament report		Final agreement?

EU Risk Assessments – Flame Retardants

Risk Assessments updates

Flame retardants have already been through an official EU risk assessment under regulation 793/93 (EC).
Risk assessment conclusions are recognised by REACH.

No restriction for 5 substances
1 substance classified as PBT, 1 substance classified as CMR cat. 1-2

Br	**Deca-BDE**	Finalized in 2005	No restriction on use
	TBBPA	Finalized in 2008	No restriction on use
	HBCD	REACH transitional system	PBT (REACH Autorization)
P/Cl	**TCPP**	Finalized in 2008	No restriction on use
	TDCP	Finalized in 2008	No restriction on use
	V6	Finalized in 2008	No restriction on use
	TCEP	REACH transitional system	CMR cat. 1-2 (REACH Autorization)

DecaBDE = Decabromodiphenyl ether
HBCD = Hexabromocyclododecane
TDCP = tris[2-chloro-1-(chloromethyl)ethyl] phosphate
V-6 = 2,2-Bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate)
TBBPA = Tetrabromobisphenol A
TCPP = tris(2-chloro-1-methylethyl) phosphate
TCEP = Tris(2-chloroethyl) phosphate

REACH process update

- Albemarle committed to register all its FRs portfolio under REACH
  - First deadline of 1st Dec. 2010 will be met for the 28 high volume substances
  - **TL-10ST,** Albemarle's TL-10ST (2,2-Bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate)) has successfully completed registration (REACH Registration # 01-2119419991-33-0000)

REACH Flame Retardant Summary

- HBCD (Hexabromocyclododecane)
  - Classified as a PBT - On the 1st Candidate List for Authorization
  - Used in EPS & XPS, with no available alternatives
    - Authorization is being sought for this application due to the importance of insulating foam
    - Application for Authorization due mid-2012
  - Current sunset date is late 2013 for all applications without Authorization

- TCEP (Tris(2-chloroethyl) phosphate)
  - Classified CMR cat. 1-2 after EU risk assessment
  - Not sustainable under REACH - alternatives available for all uses

Informed Substitution

Informed Substitution Goals

Design for the Environment U.S. EPA

- Minimize likelihood of unintended consequences
- Choose a course of action based on the best environmental and human health information that is available or can be modeled

U.S. Environmental Prote

Critical Decision Elements

Design for the Environment U.S. EPA

Alternatives should:

- Be technologically feasible;
- Deliver the same or better value in cost and performance;
- Provide an improved profile for health and environmental issues;
- Account for economic and social considerations; and
- Have potential to result in lasting change.

U.S. Environmental Protection Agency

Deca-BDE Phase-Out

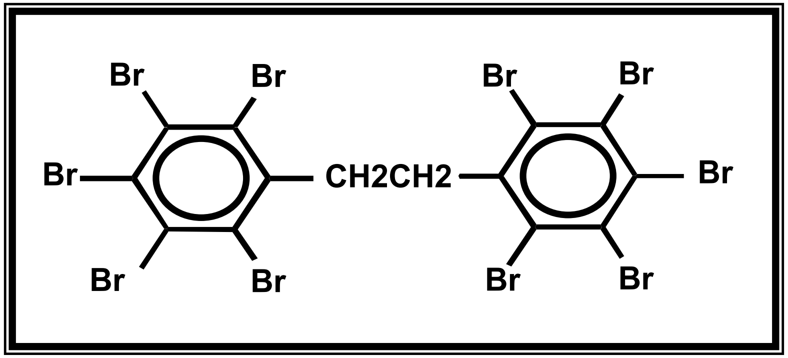
- Albemarle will phase out production and importation of Deca-BDE
- Our commitments to EPA include the following:
  - We will stop manufacturing Deca-BDE by December 31, 2013

End-Use Application	**Deadline for completion of Deca-BDE phase-out**
Wire & Cable (except transportation or military)	December 31, 2010
All other uses (except transportation or military)	December 31, 2012
Transportation and military uses	December 31, 2013

  - We will submit to EPA annual progress reports
- After the phase-out period, EPA intends to impose additional Deca-BDE testing requirements on remaining producers/importers
- After the phase-out period, EPA intends to impose a “significant new use rule” or SNUR on Deca-BDE and articles containing Deca-BDE

SAYTEX® 8010 Flame Retardant

- Most widely applicable alternative to Deca-BDE
  - Almost a direct drop-in replacement
  - UK Risk Evaluation in 2007 recommended that no risk reduction measures be taken
- Performance benefits:
  - Thermal stability
  - Non-blooming
  - Recyclability
  - UV stability for color applications

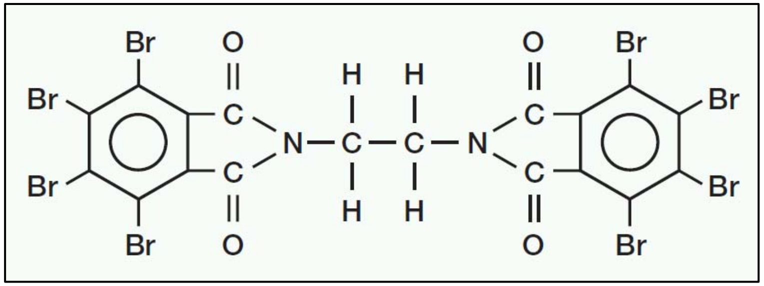


- Dust Free Saytex® 8010
  - Pellet form with a proprietary, thermally stable binder
  - Reduces cost, enhances performance, and minimizes environmental emissions

SAYTEX BT-93: High Performance FR for Automotive Wire & Cable

Advantages of BT-93 (ethylene bis-tetrabromophthalimide):

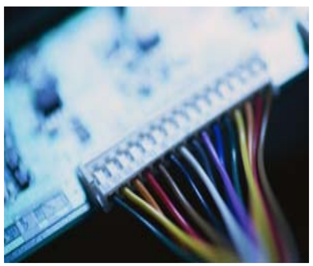
- Excellent thermal stability, suitable for T4/T5 applications
- Outstanding electrical properties
- Non-blooming, even in polyolefins
- Superior UV light stability
- Efficient flame resistance
  - Contains 67% Bromine compared to 81% for Saytex 8010.
  - Despite lower Br content, BT-93 requires same wt.% loading as Saytex 8010 to achieve similar FR performance.
- Environmental profile
  - ROHS compliant
  - Not considered a “PBT” substance
  - Insoluble; excellent chemical resistance

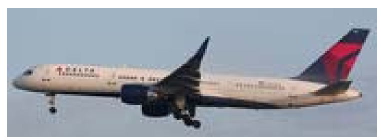


Albemarle's Polymer Solutions Market Segments

Electrical Connectors

- High performance, high thermal stability FR's
- Polymeric



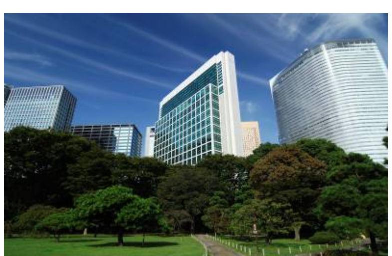


Molded Thermoplastics

- #1 deca replacement today (Saytex 8010)
- New technology launch in 2010
  - ✓ Polymeric
  - ✓ Easy to use
  - ✓ Broad range of applications

Wire & Cable

- Broad technology focus (Br, ATH, MDH)
- Leading position in EU
- New product in rollout phase



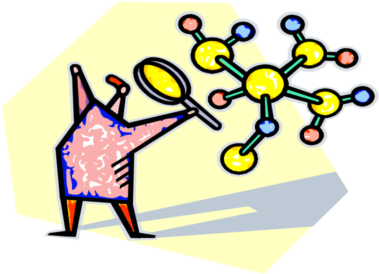
Polyurethane Foams

- Broad technology focus (Br-Cl-P)
- Production & Technical presence in fastest growing market
  - ✓ State of the art technology center
  - ✓ Manufacturing consolidation

Safety & Sustainable Use of Flame Retardants

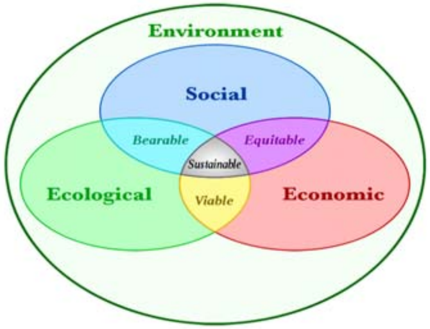
- Flame Retardant Selection
  - Physical, Mechanical, and Flammability Properties; Stability; and Recyclability of Polymer Formulations
  - Commercial Availability of FR
  - Cost

- Human Health and Environmental Criteria
  - Meets Current Regulations
  - Meets Anticipated Regulations ?



- How do you measure environmental impact of various FR's in use?
  - Life Cycle Assessment
  - Carbon Footprint, Global Warming, Energy Consumption, Ozone Depletion, Air Acidification, etc…

Albemarle Sustainability Thoughts



- Fire Safety is an important societal good
- We are a fire safety company
  - ALB will provide the right solution; we do not limit ourselves to particular products or chemistries.
- The choice of technology used to achieve fire safety should be based on sound principles
  - Full life-cycle analysis
  - Non-toxic, non-bioaccumulative products
  - Consideration of environmental and societal impacts
- We must solve the end-of-life problem for products, including electronic products
  - Products should enable recyclability

Lew et al. Evaluating the Environmental Impact of Plastics : Developing a Sustainability Index for Polymer Resins used in Electronic Enclosure, University of California Berkeley, May 2008

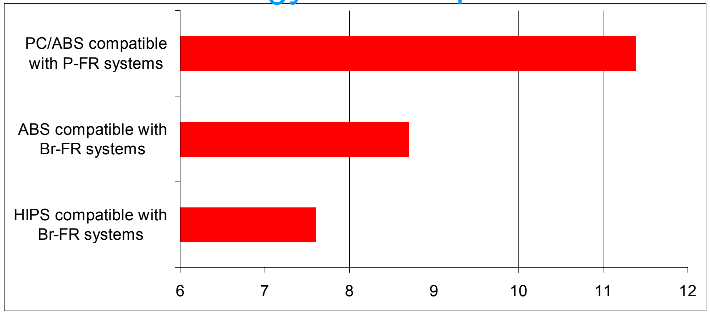
Students of Dr. Arpad Horvath: James Lew, Caroline Mahe, Trucy Phan, Claire Saint-Pierre, and Nicholas Semon

Impact Category (IC)	Abbrev.	Index Used	Equivalence Unit
Acidification Potential	AP	CML2001, Acidification Potential (AP)	kg SO_2
Carcinogens	n/a	EI99, IA, Human health Carcinogenic effects	DALY
Eutrophication Potential	EP	CML2001, Eutrophication Potential (EP)	kg PO_4
Global Warming Potential (100 years)	GWP	CML2001, Global Warming Potential (GWP 100 years)	kg CO_2
Human Toxicity Potential (HTP inf.)	HTP	CML2001, Human Toxicity Potential (HTP inf.)	kg DCB
Ozone Layer Depletion Potential (steady state)	ODP	CML2001, Ozone Layer Depletion Potential (ODP, steady state)	kg R11 (CFC-11)
Photochemical Ozone Creation Potential	POCP	CML2001, Photochemical Ozone Creation Potential (POCP)	kg Ethene
Radioactive Radiation	RAD	CML2001, Radioactive Radiation (RAD)	DALY

Equivalency / Impact Super-Category	Europe			US			Weighting Factor
	ABS	HIPS	PC	ABS	HIPS	PC	
Ecosystem Quality	0.48	0.23	1.0	0.44	0.25	0.83	0.40
Human Health	0.94	0.30	0.90	0.93	0.33	1.0	0.40
Resource Depletion	0.61	0.51	1.0	0.62	0.54	0.92	0.20
Total Index	**0.69**	**0.31**	**0.96**	**0.67**	**0.34**	**0.92**	

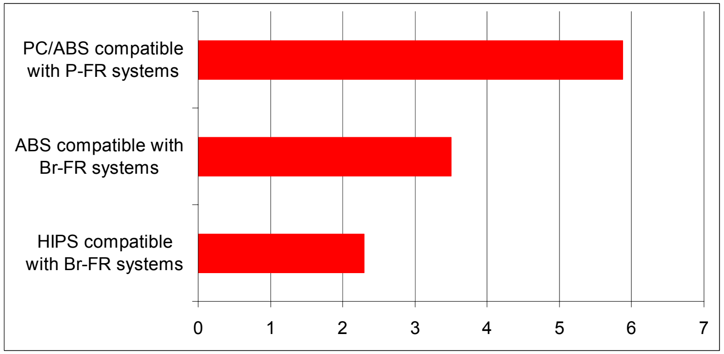
"The calculations indicate that HIPS has the least environmental impact per kilogram produced. ABS comes second, and PC falls a distant third, coming in last in nearly all of the impact categories. The U.S. and European data are not that far off from each other. The final analysis to determine the best choice must be completed by factoring in the mass of each polymer needed for the specific application."

Energy Consumption



Energy consumption (MJ per ton of resin)
Sources – Derived From: Lew et al. Evaluating the Environmental Impact of Plastics : Developing a Sustainability Index for Polymer Resins used in Electronic Enclosure, University of California Berkeley, May 2008

Global Warming Potential (GWP)



Global Warming Potential (GWP) quantification (kg-CO_2-Eq. per ton of resin)
Sources - Derived from: Lew et al. Evaluating the Environmental Impact of Plastics : Developing a Sustainability Index for Polymer Resins used in Electronic Enclosure, University of California Berkeley, May 2008

PC/ABS alloy - 70% PC + 30% ABS

To achieve sustainability...

- **Our new product development will focus on**
  - Polymeric solutions, big molecules
  - Reactive products that become bound to the final polymer
  - Mineral products

- **Releases of all product to the environment must be minimized**
  - We will champion the implementation of measures throughout the supply chain to minimize emissions of persistent compounds
  - Engage distributors, customers, and competitors in programs such as VECAP to eliminate all products from the environment

[redacted]

The next generation of eco-friendly fire safety

GreenArmor™

- First product in our family of green solutions

- non-bioaccumulative
- superior toxicity profile
- excellent recycle capability
- exceptionally broad application profile

- Polymeric flame retardant

- Highly stable product lends itself to efficient recycling of plastics

- Emissions to the environment are minimized, when combined with other good practices such as the Voluntary Emissions Control Action Program

Eliminating Emissions To The Environment Is Of The Utmost Importance For Sustainability

- **Voluntary Emissions Control Action Program**
  - **V**oluntary – producer and user implemented
  - **E**missions – identify sources of BFR emissions
  - **C**ontrol – reduce, minimize and where possible eliminate emissions
  - **A**ction – dynamic, continuous process
  - **P**rogram – focus on best practices to eliminate emissions

VECAP™

VECAP™ is an Industry Program that can be applied to all polymer additives to prevent potential emissions and save valuable raw material

ALBEMARLE CORPORATION

Chemtura

ICL Industrial PRODUCTS

Reduce Levels of Environmental Emissions of Flame Retardants

VECAP addresses many stages of the Life-Cycle

- **Manufacturing**
  - Production
  - Packaging
  - Shipping
- **Processing**
  - Dust from unloading and feed operations
  - Leaks in feed equipment
  - Improper clean-up of spills
- **Waste disposal**
  - Residues in packaging
  - Poorly treated wastewater from system wash-outs
  - Waste not reprocessed

We are asking users to:

Commit to **VECAP** Code of Good Practice

Perform self assessment and Mass Balance; develop baseline emissions to ensure progress is measurable

Create and implement emissions reduction plan

Utilize third-party verification audits as needed

VECAP in Action – Best Available Practices for Handling Packaging


There are different types of packaging, mainly spill in 20-25 kg bags (PE or paper) and big bags of 500 or 1000 kg.

Best technique for 20-25 kg bags

1. Start the ventilation system. Put the bag under the ventilation system on top of the funnel or other filling opening.

2. Place the bag in such a way that the fill spout is facing the operator. Cut the bag on the opposite side of the fill spout.

3. Turn the bag with cut side down to empty bag.

4. Shake bag vigorously.

5. Notice the spout. If the bag was cut on the opposite side, the fill spout would be full of product. Notice the exhaust port on the ventilation system. The exhaust hood should be adequate to capture the fine dust.

6. Roll up bag to get all of the air out.

7. Place rolled up bag in a plastic bag for disposal.

8. Close the plastic bags and put this one full of empty paper bags in a shipping container for proper disposal.

VECAP Europe - Best Available Technique for Emptying Bags 3

Problem

- Discarded packaging can retain small amounts of product
- Product has the potential to get into the environment, depending on end-of-life practices for empty packaging

Solution

VECAP Best Available Technique (BAT) for Emptying Packaging Document and Poster


Best technique for big bags of 500 or 1000 kg

1. Check if ventilation system is running. Mount big bag above Hopper.

2. Open bottom closures.

3. Secure sack to Hopper to prevent spillage.

4. Product should discharge by gravity.

5. Shake all Corners of sack vigorously.

6. Shake all four corners of sack vigorously.

Take care that the empty packaging is folded carefully and packed into a PE plastic bag for disposal. Close the plastic bag and put this one full of empty bags in a shipping container for proper disposal.

For further information: contact the VECAP Product Steward, Paul Adriaenssens at qualipa@skynet.be or visit www.vecap.info

VECAP is a voluntary initiative of the European Brominated Flame Retardant Industry Panel – EBFRIP together with the industry's global organisation, the Bromine Science and Environmental Forum – BSEF

EBFRIP BSEF

4 VECAP Europe - Best Available Technique for Emptying Bags

These techniques can be applied to all polymer additives to prevent potential emissions and save valuable material for use, rather than waste

Conclusions

- Flame Retardants provide a valuable role in our society
  - Prevent ignition
  - Delay the spread of fires
  - Delay the time of flashover to enable people time to escape
- It is important that Flame Retardants are safe in use
- Regulations that are being developed worldwide provide the platform to achieve this goal with a level of confidence
- Emissions of polymer additives to the environment must be minimized
- GreenArmor™ is the first product in Albemarle Corporation's Earthwise™ family of sustainable solutions

ALBEMARLE®

Connect with www.Earthwiseinside.com

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Firesafetyforall.com
Ourgreenlab.com

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Earthwise Inside

Join our group: Our green lab

YouTube.com/Earthwiseinside

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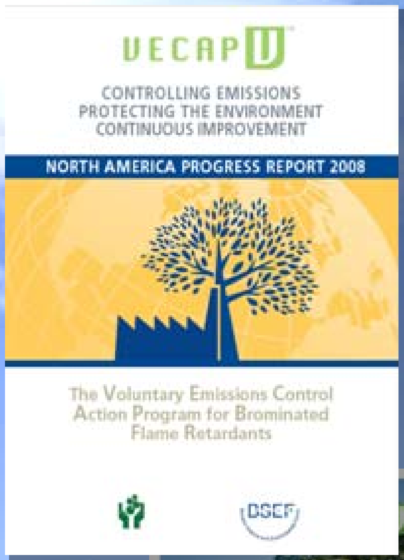

Thank you

www.albemarle.com

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We CaN DO ThAt SM

Responsible Care®
OUR COMMITMENT TO SUSTAINABILITY