Six Classes

The Power of Green Chemistry

Chemistry for the 21st Century

Dr. Robert Peoples
President
Environmental Impact Group, LLC
Six Classes Discussed

1. Highly fluorinated chemicals
   - Stain and water repellants…

2. Antimicrobials
   - Triclosan, triclocarban…

3. Flame retardants
   - Brominated, chlorinated, phosphate

4. Bisphenols and phthalates
   - Plastic additives…

5. Organic solvents
   - benzene, methylene chloride…

6. Certain metals
   - lead, mercury, chromium, cadmium, arsenic…
Big Q:

Do we need it?
What we know!
In the past 300 Years

Mankind has:

• Mastered atomic theory
• Learned to manipulate atoms
• Harnessed petroleum for energy and building blocks
• Created molecules that never existed in nature
• Revolutionized agriculture
• Built better, stronger, cheaper, durable *(persistent*) materials
• Exceeded Earth’s capacity
$4,000,000,000,000,000,000
or
$4 \times 10^{12}$
Unintended Consequences

- Population growth
- Water scarcity
- Food contamination
- Collapse of fisheries
- Loss of biodiversity
- Climate change
- Extinctions: “The death of birth”
- Deforestation
- Persistence / bioaccumulation
- Body burden

*In the eyes of Nature our current business models are not sustainable!*
Do we need it?

When the answer is yes, there is a better way!
Einstein has the answer

*Insanity*: doing the same thing over and over again, and expecting a different result.
Green Chemistry

Green chemistry is the **design** of chemical products and processes that **reduce or eliminate** the use and/or generation of hazardous substances.
12 Principles of Green Chemistry*

1) Prevent waste
2) Maximize atom economy
3) Design less hazardous chemical syntheses
4) Design safer chemicals and products
5) Use safer solvents and reaction conditions
6) Increase energy efficiency
7) Use renewable feedstocks
8) Avoid chemical derivatives
9) Use catalysts, not stoichiometric reagents
10) Design chemicals and products that degrade after use
11) Analyze in real time to prevent pollution
12) Minimize the potential for accidents

Building a Global Sustainable Chemical Enterprise

$\pm 88 \rightarrow 85,000+$
Building a Global Sustainable Chemical Enterprise

+/- 88 \rightarrow 85,000+

Lessons from Nature
The Peacock Effect
Morphotex™ (Teijin)
How does a Gecko Hold on?

Gecko – “sticking” without adhesive

Biomimicry
How does a Gecko Hold on?

- van der Waals interactions between the finely divided setae and surface hold geckos
- almost 500,000 setae/foot
- each setae is tipped with 100 - 1,000 spatulae

Gecko Tape

Lesson: Nature found a way to make things stick really well without adhesives.
Biobased Developments Accelerating

**New Biobased Building Blocks**

- Ethylene
- Butanol
- Succinic acid
- Levulinic acid
- Lactic acid
- Acrylic acid
- Adipic acid
- PDO / BDO
- Caprolactam
- Terephthalic acid
- more to come

**New Water Based Processes**

- Aldol condensations
- Michael additions
- Mannich reaction
- Grignard-type additions
- Metathesis reactions
- Benzoin condensation
- etc.

![Chemical structures and reaction mechanisms]
Green Chemical Growth in World Markets: 2011-2020

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Why is GC Important?

- Reduces human and environmental impacts
  - Meets society’s expectations
  - Ensures right to operate
  - Enhances corporate reputation
  - Drives innovation
  - Drives competitive advantage
  - Enhances recruiting
  - Avoids/Reduces:
    - Costs
    - Waste
    - Energy use
    - Material use
    - Risk

= $

Proven Approach
Watch-outs

- Unintended consequences
- Regrettable substitutions
- Lack of leadership support
- Failure to ask the right GC questions
- Incremental expansion vs. new technology
- Too hard
- Too far in the future
- No one pays for green
GC Pledge

No new chemical, or process by which that chemical would be manufactured, should be commercialized without a complete green chemistry screen for human health and environmental impacts.
What can you do?

- Ask: Do we really need this chemical?
- If yes, seek a green chemistry alternative?
- Get leadership behind the drive.
- Hire people with training in green chemistry.
- Make a personal commitment to action.
Getting Started

- Step 1: Find out what is in your products today
- Embrace the GC Pledge: nothing new/replaced without modern testing protocols
- Employ Life Cycle Assessment (Analysis)
  - requires expertise: hire, contract to provide
  - go cradle to cradle vs. cradle to grave
  - evaluate recycling at end of life
- Tell your suppliers remove these classes within 2 years - collaborate
- Formulator’s Roundtable
- Chemical Manufacturer’s Roundtable

Get started!
Tools to Get Started

See Fact sheet for more details
Getting Started

✓ Create metrics
✓ Create goals
✓ Embrace transparency
✓ Publish sustainability report
✓ Find senior management champion
✓ Speak up and be heard – the time is now
✓ Ask those who are doing how
✓ Create a challenge grant: e.g. oil and stain repellency

Make a decision TODAY to make a difference, for you, your family, your grandchildren, for society, for our planet!
Presidential GC Award Winners

P&G: Replaced petroleum based oils in paints with biobased ingredients and reduced solvent use by >50%

BASF: Automobile paint primer cut VOCs by >50% and eliminated isocyanates, reduced amount of primer needed and reduced waste to near zero.

Shaw Industries: EcoWorx™ tiles eliminated bitumen, PVC, or polyurethane in carpet tile and can now be easily recycled.

Kraton Perf. Polymers: Sea water purification by reverse osmosis is one vital technology. Kraton developed halogen-free membranes using less solvent. Additional Plus - can purify hundreds of times more water vs. traditional membranes, save 70 percent in membrane costs, and save 50 percent in energy costs.

More detail: go to resource slide under Presidential Green Chemistry Awards
Resource Sheet

Books:

**General**

*Confessions of a Radical Industrialist*, by Ray C. Anderson

*The Ecology of Commerce*, by Paul Hawken

*Chasing Molecules*, by Elizabeth Grossman

**Textbooks**

Green Engineering, Environmental Conscious Design of Chemical Processes by David T. Allen and David R. Shonnard

Green Chemistry and Engineering, A Practical Design Approach by Concepcion Jimenez-Gonzalez and David J. C. Constable

**Tools**


GreenSuite – [www.chemply.com](http://www.chemply.com)

ToxCast™ - [http://www.epa.gov/ncct/toxcast](http://www.epa.gov/ncct/toxcast)

TiPED – [www.tipedinfo.com](http://www.tippedinfo.com)

DfE – [www.epa.gov/dfe/](http://www.epa.gov/dfe/)


UL – [www.ul.com](http://www.ul.com)


Isustain - [https://www.isustain.com/](https://www.isustain.com/)

EIOLCA - [http://www.eiolca.net/](http://www.eiolca.net/)

**Resources:** Annual PDF of US EPA Presidential Green Chemistry Challenge Awards, [http://www2.epa.gov/green-chemistry/presidential-green-chemistry-challenge-winners](http://www2.epa.gov/green-chemistry/presidential-green-chemistry-challenge-winners)

Yale University - [http://www.greenchemistry.yale.edu/](http://www.greenchemistry.yale.edu/) (Dr. Paul Anastas and Dr. Julie Zimmerman)

UC Berkeley - [http://bcgc.berkeley.edu/](http://bcgc.berkeley.edu/) (Dr. Martin Mulvihill)

University of Nottingham - [http://www.nottingham.ac.uk/chemistry/index.aspx](http://www.nottingham.ac.uk/chemistry/index.aspx) (Dr. Martyn Poliakoff)


University of Oregon – [http://greenchem.uoregon.edu/](http://greenchem.uoregon.edu/) (Dr. James Hutchison, Dr. Julie Haack)


Make the Pledge: *No new chemical, or process by which that chemical would be manufactured, should be commercialized without a complete green chemistry screen for human health and environmental impacts.*
The key to success is getting start.