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Fan of the Week
Barry LeClair,
High School Science Teacher,
Biology, Chemistry, AP Chemistry, Physical Science,
and Information Technology

Quote in reference to: http://bit.ly/ForensicToxicology

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Thursday, August 18, 2016

Crystallography as a Drug Design and Delivery Tool

Vincent Stoll, Research Fellow and Associate Director of Structural Biology, Abbvie
Robert Wenslow, Vice President Business Development, Crystal Pharmatech
Andrew Brunskill, Associate Principal Scientist, Merck

Thursday, September 1, 2016

Future Protective Materials for First Responders, Football Players, and Astronauts: Shear Thickening Fluids

Norman Wagner, Chemical & Biomolecular Engineering, University of Delaware & co-founder of STF Technologies LLC
Aaron Forster, Materials Research Engineer, National Institute of Standards and Technology

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Chemophobia: How We Became Afraid of Chemicals and What to Do About It

Slides available now! Recordings will be available to ACS members after a few weeks

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Chemophobia: How We Became Afraid of Chemicals and What to Do About It

James Kennedy
Chemistry Teacher
Haileybury, Australia
chemophobia
Irrational fear of compounds perceived as synthetic
Chemophobia

• Irrational fear of compounds perceived as synthetic
• "Non-clinical phobia"
• Caused and cured by the spread of information
• Chemists are partly responsible for chemophobia
• Prevalent: "chemicals" are a top 10 public concern (UMich, 2008)

Introduction: Quick overview of the reputation of chemistry, chemicals and chemists
Word Associations: ‘Chemistry’

- school
- intimidating
- methodical
- serious
- secretive
- hard
- focus
- microscopic
- inaccessible
- accidents
- smells
- medicine
- elements
- labs
- drugs

Figure 2.2: Engagement/interest in chemistry (%)

- 43%
- 42%
- 13%

Q.4A How engaged or interested are you with chemistry?
Base: All respondents (21,064 UK adults 16+)

Mean score: 4.3
Attitude towards chemicals is slightly better

**General attitude towards chemicals**

- Everything is made of chemicals
- Everything including water can be toxic
- Natural chemicals are not safer
- Not all chemicals are dangerous/harmful
- Not all chemicals are man-made

<table>
<thead>
<tr>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Attitude towards chemists is great!

- Do not make a difference in the world
- Dishonest
- Unapproachable
- Unenthusiastic
- Boring

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>Tend to disagree</th>
<th>Neutral</th>
<th>Tend to agree</th>
<th>Strongly agree</th>
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Chemists make a valuable contribution
Why improve the reputation of chemistry?

- a healthy democracy needs informed citizens
- science funding relies ultimately on how much people value science
- helps us to realise the importance of our own work

“Nothing in life is to be feared. It only needs be understood.”
26% of US respondents agreed

“It is impossible for recycled water to be treated to a high enough quality that I would want to use it.”

Survey by Paul Rozin et al. 2,670 people in several American cities were asked.
“It’s water. Having studied the engineering behind it, I’d happily drink it every day. It’s that safe.” – Bill Gates, 2015

Purified water extracted from toxic waste
Pure \( \text{H}_2\text{O}(l) \)

Purified water extracted from a mountain spring
Pure \( \text{H}_2\text{O}(l) \)
Which would you rather drink?

• I have a strong preference for the water from toxic waste
• I have a slight preference for the water from toxic waste
• I have no preference
• I have a slight preference for the water from a mountain spring
• I have a strong preference for the water from a mountain spring

Part 1: Evolutionary origins of chemophobia as an irrational psychological quirk
Contagion

• Paul Rozin, University of Pennsylvania

• By touching something we find disgusting, a previously neutral or even well-liked item can acquire—permanently—its properties of grossness.

Mark Schaller
University of British Colombia

“behavioural immune system”
“A suite of psychological mechanisms designed to detect the presence of disease-causing parasites in our immediate environment, and to respond to those things in ways that help us to avoid contact with them.”

April 2011 vol. 20 no. 2 99-103
Mark Schaller
University of British Colombia

“behavioural immune system”
“...the system responds to an overly general set of superficial cues, which can result in aversive responses to things (including people) that pose no actual threat...” – Mark Schaller

We eat a watermelon that’s gone bad, which makes us ill

“Eww... I don’t like melon”
DDT is sprayed excessively

“I don’t like artificial chemicals”

Megan Oaten
Macquarie University

2009, Vol 135, No. 2 303-321
Some people prefer “chemical-free” products

• People fear parabens, sulfates, formaldehyde, MSG the most
• Labels make irrelevant ‘free from’ claims

Some people prefer “natural” products

• What does natural mean?
  • UK: “Produced by nature”
  • Canada: “Processed only minimally” and “with nothing added or removed”

• Is anything natural?

claims to be “natural”
Which of the claims on the front of the bottle are INCORRECT?

- Pure only
- Pure & natural
- Natural & organic
- Organic & pure
- Pure, natural & organic

**Audience Survey Question**

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

Which of the claims on the front of the bottle are INCORRECT?
Part 2: Origins of seven types of modern chemophobia

1: Anti-vaccination (1798)

- **Started immediately after the introduction of smallpox vaccine by Edward Jenner in 1798**

*First arguments*
- “Vaccines don’t work”
- “Smallpox vaccine turns you into a cow”
- “Injecting is unchristian”
- “Mandatory injections erode our personal liberties”

- 1802: Anti-vaccination cartoon in newspaper
- 1879: First anti-vaccination society in the US
- 1885: Massive anti-vaccination protest in Leicester, UK
2: Organic food (1940)

- Started immediately after the introduction of DDT (1939)

First arguments
- “Mycorrhizal association is being ignored”
- “Health of our soils is being depleted”
- “The use of agricultural chemicals is unsustainable”

- Requires the misconception that pesticides are not sprayed onto organic crops... but they are!
  - Spinosad insecticide (irritant)
  - Lime sulphur (corrosive; causes blindness if sprayed in eyes)
3: Anti fluoridation (1945)

- **Started immediately after Grand Rapids water fluoridation experiment (1945)**
- 60% reduction in tooth decay over 15 years

**First arguments**
- “Communist plot to damage our health”
- “Goes against libertarian values”

4: Paleolithic diet (1985)

- **Started in 1985 when Eaton & Konner published “Paleolithic Nutrition” paper in NEJM**

**First arguments**
- “[Modern western diets] contribute to heart disease, hypertension, diabetes & cancer”
- “Our bodies haven’t evolved to eat farmed foods”
- Fad diet based on what humans might have eaten 10,000 to 40,000 years ago
- Meat, fish, vegetables, fruit; no farmed foods
- Direct response to growing nutritional concerns in the 1980s
5: Anti-GMO (1987)

- Started in 1987 when the first genetically-modified organism to be introduced to the environment was destroyed by protesters
  - Anti-corporate bias
  - Anti-gene-patenting
6: “Chemtrails” (1996)

- Started in 1996 after the US Air Force published “Weather as a Force Multiplier: Owning the Weather in 2025”

First arguments
- “Climate control”
- “Chemical weapon testing”
- “Radar mapping”
- “Drugging the population”
- Fragmented group with varied beliefs and almost no evidence

Chemophobic movements are immediate and reactionary responses to external stimuli

<table>
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<th>Movement</th>
<th>Origin</th>
<th>Stimulus</th>
<th>Time lag</th>
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<tr>
<td>Chemical-free</td>
<td>(ancient)</td>
<td>Innate biophilia</td>
<td>n/a</td>
</tr>
<tr>
<td>Anti-vaccination</td>
<td>1798</td>
<td>Vaccinations</td>
<td>&lt;4 years</td>
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<td>Organic foods</td>
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<td>DDT</td>
<td>&lt;1 year</td>
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<tr>
<td>Anti-fluoridation</td>
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<td>Fluoridation</td>
<td>&lt;1 year</td>
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<tr>
<td>Paleolithic diet</td>
<td>1985</td>
<td>Declining nutrition</td>
<td>&lt;2 years</td>
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<tr>
<td>Anti-GMO</td>
<td>1987</td>
<td>GMOs</td>
<td>&lt;6 months</td>
</tr>
<tr>
<td>Chemtrails</td>
<td>1996</td>
<td>Research paper</td>
<td>&lt;6 months</td>
</tr>
</tbody>
</table>

Conclusion
- Haters emerge on day one
- Their arguments evolve
• Chemical-free
  1. Anti-vaccinations
  2. Organic foods
  3. Anti-fluoridation
  4. Paleolithic diet
  5. Anti-GMO
  6. Chemtrails

Uninformed and not actively interested

NEGATIVE       NEUTRAL       POSITIVE

Part 3: Events that amplified chemophobia even further
Audience Survey Question

Which of these had the greatest influence in sparking the modern environmental movement?

• Rachel Carson’s *Silent Spring*, 1962
• Apollo missions, 1961-1972
• Industrial disasters (e.g. Times Beach, Bhopal), 1960s-80s
• Fall of the Berlin Wall, 1989
• Social media, late 2000s onwards
Published in 1962

By Rachel Carson, a marine biologist

Worked for US Fish & Wildlife Service (USFWS)

“[Chemicals are] the sinister and little-recognised partners of radiation... entering into living organisms passing from one to another in a chain of poisoning and death”
DDT was sprayed liberally on farms, people, beaches, houses, suburbs.
Dichlorodiphenyltrichloroethane (DDT)

- Synthetic insecticide
- Developed in 1939
- DDT destroys hundreds of types of insects at once
- Eliminates malaria and lice very effectively
- Inventor Paul Müller was awarded a Nobel Prize in Medicine in 1948

Dichlorodiphenyltrichloroethane (DDT)

- DDT bioaccumulates
- Neither metabolised not excreted
- DDT is a lipophile (binds to lipids)
- Highly stable compound
- 8-year half life in animals
- Mixed evidence regarding health effects in humans
- Silent Spring made people afraid of chemicals – especially artificial chemicals like DDT
NASA image AS8-14-2383
“Earthrise”
Apollo 8 mission
December 24, 1968

NASA image AS17-148-22727
“The Blue Marble”
Apollo 17 mission
December 7, 1972
Photographs of the Earth in its natural state amplified our innate biophilia

We discovered our planet’s natural beauty for the first time
Bastion of the modernist movement
Pruitt-Igoe urban housing project, 1954
St. Louis, Missouri, USA

Demolition of Pruitt-Igoe signalled the beginning of postmodernism
1971-72, St. Louis, Missouri, USA
Modernism (pre-1972) | Postmodernism (post-1972)
---|---
Objective reality exists | All reality is merely a social construct
Statements of historians and scientists are either true or false | There is no ‘truth’ – my version of the truth can be as true as yours
Humanity is becoming smarter, more prosperous, more humane | Technological achievements are not progress, they’re regress – they enable us to torture and oppress (note WW2)
Logic applies universally | Logic is a social construct with no metaphysical authority
Language reflects reality | Even if there was a ‘truth’, there’d be no way to express it

Postmodernism devalued science & experts

- With the internet, anyone can have an opinion
- “The cult of the amateur” has emerged
- Experts are no longer automatically trusted
- Scientific truth is just one opinion
- All parties—no matter how absurd or unproven their ‘facts' and claims—should be treated equally
1962
Made us fear chemicals – especially artificial chemicals

1969
Amplified our innate biophilia – made us love our natural world

1972
A symbol of our ebbing trust for experts and scientists – postmodernism is born

Events that fuelled chemophobia even further

- Thalidomide banned in 1961
- Minamata Bay disaster, Japan 1968
- Smoking and tobacco companies’ cover-up 1950s-70s
- Agent Orange used from 1961-71
- Times Beach disaster, Missouri 1970s
- DDT banned 1972
- Ozone depletion due to CFCs discovered 1974
- Love Canal disaster, New York 1976
- Bhopal disaster, India 1984
- Chernobyl disaster 1989
# TV Documentaries

<table>
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<tr>
<th>BIOLOGY</th>
<th>CHEMISTRY</th>
<th>PHYSICS</th>
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<tbody>
<tr>
<td>Life</td>
<td>Chemistry – A Volatile History</td>
<td>Wonders of the Solar System</td>
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<tr>
<td>Planet Earth</td>
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<td>Wonders of the Universe</td>
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<tr>
<td>Blue Planet</td>
<td></td>
<td>Human Universe</td>
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<tr>
<td>How Earth Made Us</td>
<td></td>
<td>Wonders of Life</td>
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<tr>
<td>Wonders of Life</td>
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<td>Cosmos</td>
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<tr>
<td>Your Inner Fish</td>
<td></td>
<td>How the Universe Works</td>
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<tr>
<td>Inside the Human Body</td>
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<td>Can We Make a Star on Earth?</td>
</tr>
<tr>
<td>First Life</td>
<td></td>
<td>Journey to the Edge of the Univ.</td>
</tr>
<tr>
<td><em>and so many more...</em></td>
<td><em>...that’s it.</em></td>
<td><em>and so many more...</em></td>
</tr>
</tbody>
</table>

**Our only TV documentary**

- Chemistry: A Volatile History
- BBC Four (2010)
- Problems
- Episodes
  - 1: Discovering the Elements
  - 2: The Order of the Elements
  - 3: The Power of the Elements
  - *...that’s it!*

Jim Al-Khalili
Professor of Theoretical Physics
Part 4: Current efforts to fight chemophobia

Current efforts to fight chemophobia

• “Chemicals are everywhere”

• “The dose makes the poison”

• “Natural isn’t always safe”

• “Natural/artificial is a construct”

• They’re all reactionary
“Chemicals are everywhere”

INGREDIENTS INCLUDE:
- Carotene
- Tocopherol
- Riboflavin
- Nicotinamide
- Pantothenic acid

All ingredients naturally found in apples.

“Chemicals are everywhere”

Food is chemicals

Green Tea

Ingredients: water, catinohin, epicatechin, gallic acid, caffeine, quercetin, epigallocatechin gallate, epigallocatechin, flavonols, glycosides, chlorogenic acid, somanrubicin acid, thymoquinone, theobromine, theophylline, quercetin, kaempferol, myricetin.

Olive Oil

Ingredients: triacylglycerols, diacylglycerols, hydroxytyrosol, tyrosol, chlorophyll, carotenoids, tocopherol, phytosterols, oleic acid, linoleic acid, palmitic acid, stearic acid, limonene, acid, glycerol, phosphates, sterols.
AN ALL-NATURAL BANANA
"The dose makes the poison"

APPLE SEEDS
PEARS
POTATOES
COURGETTES

CONTAIN AMYGDALIN  
-0.6g/kg of seeds

CONTAIN FORMALDEHYDE  
-0.06g/kg

CONTAIN SOLANIN  
(higer in green potatoes)

CONTAIN CUCURBITACIN E  
(higer in bitter courgettes)

ALL OF THE FOOD ITEMS ABOVE CONTAIN NATURAL CHEMICALS THAT ARE TOXIC TO HUMANS. HOWEVER, THEY ARE USUALLY PRESENT IN VERY SMALL AMOUNTS, FAR BELOW THE HARMFUL DOSE.

JUST BECAUSE A CHEMICAL IS PRESENT, DOES NOT MEAN THAT IT IS HARMFUL IN THE AMOUNT PRESENT.
“The dose makes the poison”

- Dihydrogen monoxide
- LD$_{50}$ is about 6 litres
- Chi Tau ‘hazing ritual’, 2005
  - 1 dead, 2 comatose
- KDND radio ‘Wee for a Wii’ competition
  - 1 death
- $[\text{Na}^+] \downarrow \downarrow$
- Brain swelling

---

“Natural isn’t always safe”

Samuel J. Lord

sam@everydayscientist.com
Natural/artificial is a construct

• Blur the boundaries between natural and artificial

• This erodes the core belief upon which chemophobia relies
NATURAL “CORN”, 7000 B.C.

- Peel it by hammering separately with a hard object.
- Tastes like very dry, raw potato.
- 5-10 very hard kernels.

8 KNOWN VARIETIES

- 75.2% WATER
- 1.9% SUGARS
- 23.1% OTHER (mostly starch)

ONLY FOUND IN CENTRAL AMERICA

ARTIFICIAL CORN, 2014

- Steam cooks in minutes.
- Easy to peel. Up to 1000 times larger.
- 190 mm.
- ~1000 times larger.

- 200 VARIETIES.
- 25-fold increase.

Available in five colours:
- Colorful (Red, Yellow, Yellow/Green, Red/Green, Blue/Green)

- 73.2% WATER
- 6.6% SUGARS
- 20.2% OTHER (still rich in starch)

GROWN IN 60 COUNTRIES

NATURAL “WATERMELON” ~3000 B.C.

- Open with a hammer or sharp object.
- Extremely bitter taste. Some varieties are bitter-sweet.
- Causes inflammation.
- 18 seeds. Very rich in fat. They taste bitter and extremely bitter.

6 KNOWN VARIETIES

- Found in Namibia & Botswana

90.0% WATER
1.5% SUGARS
9.5% OTHER (mostly starch and fat)

GROWN IN 40 COUNTRIES

ARTIFICIAL WATERMELON, 2014

- Deliciously sweet, 3 x juicier than the traditional regular watermelon.
- Different shapes available:
  - 36% Round / oval
  - 18% Fruit-shaped
  - 18% Heart-shaped
  - 6% Star-shaped

- Available in four colours:
  - Crimson
  - Yellow
  - Red/Green
  - Blue/Green

- 91.5% WATER
- 5.2% SUGARS
- 3.3% Starches
- 0.0% Other

GROWN IN 40 COUNTRIES
Part 5: How children are introduced to chemistry

“Never eat in the lab”

“Assume everything in the lab is toxic & corrosive”

“Don’t pour that back into the stock solution!”

100% CHEMICAL FREE!
“When are we going to blow stuff up, sir?”

“Sir, do you know how to make meth?”
“Sir, is that the Chinese character for meth?”
Part 6: Homework

devote 5% of your time to outreach
Myths about outreach

**chemistry outreach is NOT...**
- “about giving back to the community”
- “charitable”
- “dumbed down”

**chemistry outreach is the lifeblood of our industry**
- a healthy democracy needs informed citizens
- science funding relies ultimately on how much people value science
- helps us to realise the importance of our own work

How to use that 5% ‘outreach time’

1. Tweet about your work
2. Give your ‘talk’ in local schools
   - Explain what you do as a chemist
3. Join your university’s ‘expert line’ for media commentary
4. Write articles for your school/university magazine
5. Participate in science festivals
6. Participate in your workplace’s YouTube channel
7. Write a book
How to speak to the public about chemicals

**WHAT TO SAY**
- Be passionate & positive!
- Make links between chemistry and things they care about
- Keep it simple
- Talk about your job as a chemist
- Talk about yourself
- Show them you’re human, too!
- Address the neutral 60%

**WHAT NOT TO SAY**
- “Chemicals are everywhere”
- “Everything’s made of chemicals”
- Don’t patronise them
- Don’t address natural/artificial divide unless asked
- Don’t expect evidence to change their minds
- Ignore the negative 20%
Abandon the word “chemical” as a noun

- Acid
- Solvent
- Metal
- Powder
- Crystal
- Molecule
- Compound
- Element
- Atoms

- Liquid
- Extract
- Gas
- Alloy
- Polymer
- Fibre
- Pigment
- Gel
- Solution

Oxford English dictionary

chemical (noun)
a distinct compound or substance, especially one which has been artificially prepared or purified
Abandon the word “chemophobia”

**WHAT TO SAY**
- Tell stories
- Emphasise how chemistry can help towards things we are passionate about
- Make chemistry relevant, modern, interesting and all about **molecules**
- Don’t start with the elements of the periodic table

**WHAT NOT TO SAY**
- “Chemophobia”
- “Fighting ignorance”
- “Mythbusting”
- “Debunking”
- Do not attempt the ‘deficit model’
  - “Let me show you why you’re wrong”

Focus on what people care about!

**WHAT TO SAY**
- **Chemistry of things around us**
  - Food
  - Perfumes
  - Building materials
- **Cutting-edge research that helps:**
  - Climate
  - Environment
  - Clean/cheap energy

**WHAT NOT TO SAY**
- **Elements**
  - Reminds people of school
  - We seldom encounter substances in their elemental state anyway
- **Don’t just focus on history**
  - Creates the idea that chemistry has ‘expired’ and has nothing new to offer
Great examples of chemistry outreach

- ACS Reactions
- Periodic Videos
- Outreach programs
- Theodore Gray’s books and apps

[Website image of CHEMISTRY news]

53
Finally...
The ultimate cure
The ultimate cure

• We need factual, big-budget TV documentaries about chemistry
• We need a benevolent chemistry TV personality to counteract Walter White
• Focus on **modern chemistry**
• Focus on **molecules**
• Communicate through **human stories**
  • Deep local cultural roots
• Aim for mainstream TV
• **Creative inspiration**
  • “A Bite of China”
  • spent $5m per series

The ultimate cure

• **Episode list**
  1. **Celebration** – food, cooking, wine, party drugs, f’works
  2. **Curing ailments** - medications old & new
  3. **Keeping food fresh** – preservatives, packaging, ripening
  4. **Gifts from nature** – natural compounds inc. crude oil
  5. **Seduction** – perfumes, cosmetics, aphrodisiacs
  6. **Pilgrimage** - transportation, fuels, roads, dynamite
  7. **Poison** – chemical weapons, misused drugs, toxins removed by chemical means, decaffeination, pest ctrl.
  8. **Vibrancy** – pigments, bleach, Sistine Chapel
  9. **Beauty** – clothing, furnishings, skincare, landscape materials, space missions & photos of Earth
  10. **Protection** – glass, Kevlar, condoms, iodine, immunisations, preservatives, superhydrophobics
  11. **Saying hello** – paper, pens, iPhones, smoke signals
  12. **Purity** – cleaning, religious rituals, water purification, purification of medicines, haircare, electroplating/refining
The end
Thank you

Most common poisons

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<td>64,217</td>
<td>5.7</td>
</tr>
<tr>
<td>Alcohols</td>
<td>51,344</td>
<td>4.6</td>
</tr>
<tr>
<td>Anticonvulsants</td>
<td>41,738</td>
<td>3.7</td>
</tr>
<tr>
<td>Pesticides</td>
<td>39,968</td>
<td>3.5</td>
</tr>
<tr>
<td>Bites and Envenomations</td>
<td>36,944</td>
<td>3.3</td>
</tr>
<tr>
<td>Antihistamines</td>
<td>34,804</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Poison.org; National Poison Data System (2014)
Most common poisons

<table>
<thead>
<tr>
<th>FATALITIES ONLY</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analgesics</td>
<td>133</td>
<td>19.2</td>
</tr>
<tr>
<td>Fumes/Gases/Vapors</td>
<td>86</td>
<td>12.4</td>
</tr>
<tr>
<td>Cold and Cough Preparations</td>
<td>49</td>
<td>7.1</td>
</tr>
<tr>
<td>Antihistamines</td>
<td>38</td>
<td>5.5</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>29</td>
<td>4.2</td>
</tr>
<tr>
<td>Sedative/Hypnotics/Antipsychotic</td>
<td>29</td>
<td>4.2</td>
</tr>
<tr>
<td>Cleaning Substances (Household)</td>
<td>28</td>
<td>4.0</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>26</td>
<td>3.8</td>
</tr>
<tr>
<td>Cardiovascular Drugs</td>
<td>23</td>
<td>3.3</td>
</tr>
<tr>
<td>Alcohols</td>
<td>19</td>
<td>2.7</td>
</tr>
<tr>
<td>Stimulants and Street Drugs</td>
<td>18</td>
<td>2.6</td>
</tr>
<tr>
<td>Batteries</td>
<td>17</td>
<td>2.5</td>
</tr>
<tr>
<td>Pesticides</td>
<td>17</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Poison.org; National Poison Data System (2014)

Chemistry can help to solve all 10 public health concerns

- Alcohol-related harms
- Food safety
- Healthcare-associated infections
- Heart disease and stroke
- HIV
- Motor vehicle injury
- Nutrition, physical activity and obesity
- Prescription drug overdose
- Teen pregnancy
- Tobacco use
Chemophobia: How We Became Afraid of Chemicals and What to Do About It

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