PPCP Perspectives:
Emerging Knowledge on Emerging Contaminants

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State of the Science
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PPCPs

- 1 Acronym, 2 distinct issues

http://www.diamond.ac.uk/

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Q: What chemicals do we find in the environment?

A: All the ones we are using (i.e., assuming we are looking for them)

Mostly those that are:

- Mass-produced
- Discharged into wastewater, soil & air
- Feature foreign chemical structures (i.e., organohalides)

Detection does not automatically imply a problem, however
Today’s Chemosphere

- Actual number of chemicals is unknown (=> ∞)
- 26 million organic and inorganic compounds have been documented
- 9 million were commercially available in 2005
- 240,000 are inventoried or regulated by governments worldwide
- >4,800 are produced at quantities of >1 million lbs per year
- 2,800 earmarked for toxicity testing

- Due to human activities, chemical complexity in the environment increases constantly
What do we need? What can we do without?

Case study:

Persistent biocides: societal necessity or avoidable environmental contaminants?

- Halogenated aromatics
- Mass produced and consumed as components of personal care products
- Persistent environmental contaminants
- Potentially bioaccumulative
- Toxic
- Endocrine disruptors
- Not regulated; not routinely monitored

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List of Drinking Water Contaminants & MCLs

National Primary Drinking Water Regulations

National Primary Drinking Water Regulations (NPDWRs or primary standards) are legally enforceable standards that apply to public water systems by limiting the levels of contaminants in drinking water. Visit the list of regulated contaminants with links for more details.

- List of Contaminants & their Maximum Contaminant Level (MCLs)
- Setting Standards for Safe Drinking Water to learn about EPA's standard-setting process
- EPA's Regulated Contaminant Timeline (86 KB PDF file, 1 pg) (ALL ABOUT PDF FILES)
- National Primary Drinking Water Regulations - The complete regulations regarding these contaminants available from the Code of Federal Regulations

National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause health effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems to comply. However, states may choose to adopt them as enforceable standards.

- List of National Secondary Drinking Water Regulations
- National Secondary Drinking Water Regulations - The complete regulations regarding these contaminants available from the Code of Federal Regulations

Unregulated Contaminants

This list of contaminants, which at the time of publication, are not subject to any proposed or promulgated national primary drinking water regulations under SDWA. For more information check out the list, or visit the Drinking Water Contaminant Candidate List (CCL) website.

- List of Unregulated Contaminants
- Drinking Water Contaminant Candidate List (CCL) Web Site
- Unregulated Contaminant Monitoring Program (UCM)
Primary Chemical Contaminants in SDWA

- Chemicals (~80 total)
  - Inorganic compounds (16)
    - Radionuclides (4 types/groups)
    - Elements (14)
  - **Organic compounds (~53)**
    - Non-halogenated compounds (12)
    - Halogenated compounds (~41)
    - Chlorinated compounds (40)
    - Pesticides (~24)

⇒ **75% of regulated organic DW contaminants are chlorinated organics**
Examining Our Relationship With Nature...
By Entering the Antiseptic World of...

**Triclosan (TCS)**

- Name
- Year Introduced: 1964
- Log $K_{OW}$ (at 25°C, pH 7): 4.8

**Triclocarban (TCC)**

- Name
- Year Introduced: 1957
- Log $K_{OW}$ (at 25°C, pH 7): 4.9

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Necessity: 1500 New Antimicrobial Products Since the Year 2000

- Production is increasing
- No benefits from use for the average consumer (FDA panel, 2005)
- New risks are emerging
Risk Assessment: What It Can and Cannot Tell Us

- Assesses safety concerning known risks
- Changes with growing knowledge base
- Is NOT a “safety” certificate

Chemicals that are banned today were considered "safe" in the past (i.e., PCBs, DDT)
The bactericidal agent triclosan modulates thyroid hormone-associated gene expression and disrupts postembryonic anuran development

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Cell assay: concentrations of as low as 30 ng/L alter thyroid hormone receptor mRNA expression
Effects of Triclosan on *Mytilus galloprovincialis* hemocyte function and digestive gland enzyme activities: Possible modes of action on non target organisms

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Antimicrobials: Endocrine Disruption in Rats

Short-Term in Vivo Exposure to the Water Contaminant Triclosan:
Evidence for Disruption of Thyroxine

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Do Persistent Antimicrobials Cause Endocrine Disruption in Humans?
Fate of Persistent Biocides
What is the Magnitude of Biocide Inputs to Agriculture from Sludge Recycling?

Triclosan

~48% to Ag

Soap

Chemosphere 2007, 66(2):362-369

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Are Observations from the Mid-Atlantic Region Characteristic for the U.S.?

What is the Magnitude of Biocide Inputs to Agriculture from Sludge Recycling?
U.S. Nationwide Survey: Preliminary Findings
Map of states sampled (n = 15 + New England)
Concentration of Biocides in Digested Sludge from 19 U.S. Treatment Plants

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Heidler et al., unpublished
Total mass of triclosan and triclocarban applied to U.S. soils:
approx. 581,000* ± 174,000 U.S. lbs/year (± 95% CI)

* Preliminary estimate
Findings & Conclusions

• PPCPs in the environment: Dilution is not the solution
  – ppb$_{\text{WWTP Influent}}$ $\Rightarrow$ ppt$_{\text{WWTP Effluent}}$ $\Rightarrow$ ppm$_{\text{Biosolids}}$

• Significant releases (conc. & mass) to agricultural land
  – 581,000 ± 174,000 lbs/yr of TCS & TCC alone

• Several other OWCs were observed to accumulate in sludge

• PPCPs in biosolids is an emerging issue
  – represents a significant analytical challenge
Sludge: what we know and don’t know

- Sludge composition is largely unknown
- Sludge is a concentrate of hydrophobic and “hard-to-deal-with” compounds
- Sludge quality depends on wastewater quality
- Sludge is a resource of nutrients (N, P, C, etc.) and potentially valuable (but we have to protect its quality)
Sludge: a Repository of Recalcitrant Chemistry

The JHU National Biosolids Repository

Largest collection of U.S. municipal biosolids

- Information
- Confidentiality
- Continuity

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The Long Journey From Science to Policy

Case Study: Triclosan & Triclocarban

- no proven benefit (for most current uses)
- detectable in most U.S. surface waters
- > 1M lbs/year; production up; >1,500 different products
- toxic to aquatic biota at ng/L level
- bioaccumulate in algae & earthworms
- endocrine disruptors
- contain dioxin & carcinogenic impurities
- degrade to form additional carcinogens
- persistent
- accumulate in sludge and sediment to high ppm levels
- detectable in fish, food, house dust, fetal blood and in
- 97% of U.S. breast milk samples.

=> Regulatory actions pending

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Lessons (To Be) Learned

- **Produce and use** chemicals that:
  - have natural counterpart or origin
  - degrade rapidly
  - have a good safety record

- **Avoid** chemicals that are
  - halogenated (Cl, Br, F substituents)
  - rare in nature / have random structure / mixtures
  - structurally related to chemicals of concern

- “**Wastewater**” is “raw” drinking water
Lessons (To Be) Learned

- Control chemical inputs into wastewater more tightly

- Have reasonable expectation; WWTPs are designed to clean water, not clean sludge. Treatment process sequesters pollutants in biosolids (e.g., metals and persistent biocides)

- **Pollution prevention** is the fastest, most economical and most effective way of reducing environmental pollution
  - Applicable to biocides, pharmaceuticals, personal care products, and other compounds

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