The Fates and Impact of Triclosan in the Environment

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This presentation contains information from three prior talks:


(2) Halden, RU: 2011 Dr. Leroy E. Burney Lecture at the Johns Hopkins University, Johns Hopkins Bloomberg School of Public Health, March 3, 2011

(3) Halden, RU: Congressional Briefing on Triclosan, Washington, DC, February 17, 2011

\[
\begin{align*}
\text{OH} & \quad \text{Cl} \\
\text{Cl} & \quad \text{O} \quad \text{Cl} \\
\text{Cl} & \quad \text{Cl}
\end{align*}
\]

Triclosan (TCS)

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Outline

• Triclosan: A Case Study of Unsustainable Chemistry and Our Antimicrobial Lifestyle

• Failed Public Health Protection

• Water, Soil and Air Pollution

• A Low-hanging Regulatory Fruit

• Conclusions
Is there a significant reduction in infectious illnesses?

Meta-analysis of available studies


Source: AE Aiello, 2011
No significant benefit compared to plain soap
- Bacteria
- Illness symptoms

Echoes results of 2005 FDA Panel

Source: AE Aiello, 2011
• Total of 11 studies since 1980

• Range of bacteria can survive high levels of triclosan
  – *E. coli*, *Salmonella*, *Pseudomonas aeruginosa*, *Staphylococci*, others

• Results
  – All demonstrated increased bacterial survival in triclosan
  – 7/11 cross-resistance to antibiotics
    • Isoniazid, ciprofloxacin, erythromycin, tetracycline

*Source: AE Aiello, 2011*
2005 FDA panel concluded that TCS offers no measurable benefit in common uses such as antimicrobial hand soap.

Widespread use of triclosan (TCS) has NOT lowered incident rate of infectious diseases.

TCS promotes cross-resistance to clinically important antibiotics.

TCS is an endocrine disruptor, allergen, bioaccumulates in humans and is detectable in human milk fat at ppm levels.

TCS is a major contributor to soil, water and air pollution.
Contact Time
Key to understanding TCS ineffectiveness and toxicity

5 – 10 Seconds
(ineffective)

Lifetime exposure, e.g., in aquatic organisms (toxic)

Source: US EPA
Known Environmental & Human Health Risks of Triclosan at a Glance

- Degradales (including chloroform)
- Impurities
- Persistent Environmental Contaminant
- Bioaccumulation
- Endocrine Disruption
- Cross-resistance to Antibiotics

Halden, 2011
Wastewater Treatment Plants (WWTPs) Redistribute Triclosan in the Environment

Triclosan-containing Wastewater (Sewage)

WWTP

Treated Wastewater

Sludge

Incineration

Application

Land

Air

Raw DW

Surface Water

Groundwater

DWTP

Finished DW
Wastewater Treatment Plants (WWTPs) Redistribute Triclosan in the Environment

Triclosan-containing Wastewater (Sewage) → WWTP

- Treated Wastewater
- Sludge
- Air (Incineration)
- Land (Application)

Surface Water
- Raw DW
- Groundwater

Finished DW

Groundwater

DWTP

Land

Application

Incineration
Wastewater Treatment Plants are Principal Sources of Antimicrobials in the U.S.

U.S. Wastewater Treatment Plant
Fate of Triclosan in Activated Sludge WWTP

• Aquatic Occurrence
  – 58% of U.S. streams, GW, DW
  – Ocean water
• Bioaccumulation
  – Algae
  – Crustacea
  – Fish
  – Dolphins
• Endocrine Disruption
• Other Impacts
  – Behavioral changes
  – Immuno-toxic effects
  – Growth impairment


Source: http://www.dolphinsec.com/images/Dolphin.jpg
Contaminated Sediment

Wastewater treatment plant

Effluent

#1 #2 #3 #4 #5

1100 meters downstream

Baltimore, MD

Washington, D.C.
Triclosan used 45 years ago is still present today in U.S. sediments.
Wastewater Treatment Plants (WWTPs) Redistribute Triclosan in the Environment

Triclosan-containing Wastewater (Sewage) → WWTP → Treated Wastewater → Sludge (Application to Land) → Land

Air

Incineration

Raw DW → Surface Water ↔ Groundwater

DWTP → Finished DW
<table>
<thead>
<tr>
<th>Compound</th>
<th>2009 TNSSS EPA</th>
<th>2001 EPA Samples (ASU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triclocarban</td>
<td>36</td>
<td>39</td>
</tr>
<tr>
<td>Triclosan</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Ciprofloxacin</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Ofloxacin</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Cimetidine, 4-Epitetracycline, Miconazole, Tetracycline</td>
<td>0.5 – 2.5</td>
<td>1 - 2</td>
</tr>
</tbody>
</table>


Triclosan and triclocarban are the most abundant PPCPs in sludge
TCS and TCC are only two of 72 drugs monitored by EPA Method 1694.

Yet, these two antimicrobials account for >60% of the mass of all drugs detectable in sewage sludge.

Contaminated Land

Approximately 140,000 lbs/yr of Triclosan and 290,000 lbs/yr of Triclocarban are applied inadvertently on U.S. agricultural land as a result of sewage sludge disposal.

This presents a pathway for contamination of food with antimicrobials and drug-resistant microbes.

Triclosan Exhibits Half-life of 0.5 Years in Agricultural Soil

(During this study, no measurable loss of triclocarban was observed)

Walters, McClellan, Halden; Water Res. 44: 6011-6020 (2010)
Wastewater Treatment Plants (WWTPs) Redistribute Triclosan in the Environment

Triclosan-containing Wastewater (Sewage) → WWTP

- Treated Wastewater
- Sludge
  - Incineration
  - Application
    - Air
    - Land
- Surface Water
- Groundwater
- DWTP
  - Finished DW

Raw DW
Traces of toxic dioxin (TCDD) are present in commercial grade triclosan and additional dioxins can form during incineration.

*Doudrick et al. ACS Book (Halden, ed.) pp. 469-481 (2010)*
Contaminated Air

Triclosan is a Precursor of Carcinogenic Dioxins

Incineration of sewage sludge contaminated with triclosan and its derivatives is suspected to be a major contributor to dioxin emissions in the U.S.

Modeling results suggest that triclosan accounts for at least 3.6% and up to 100% of dioxins emitted from sewage sludge incinerators (which happen to be exempted from routine monitoring)

• No regulation of dioxins in sewage sludge incinerators

• Medical, municipal, and hazardous waste incinerators: Regulatory range 0.2 to 2.3 ng TEQ/dscm

• EPA reported 6.87 ng TEQ/kg sewage sludge incinerated

• At avg. exhaust 8 m³/kg sludge, this is equivalent to 0.86 ng TEQ/dscm

• **3 Times** the lowest standard for other incinerators!
Environmental Occurrences

Toxic Threshold Values

Toxic Levels: Algae in Surface Waters (Triclosan)

Near-Toxic and Toxic Levels for Crustaceans: Triclosan in Surface Water and Sediment Pore Water

Toxic Levels for Microbes: Triclosan in Sediment & Biosolids

Human Exposure & Health Risks

Percent of samples or products that contain triclosan

**People**

- Breast milk: 97%¹
- Americans over age 6 (urine): 75%²
- Cord blood: 47%³

**Environment, Food & Water**

- Rivers and streams: 58%⁴
- Tap water and food: Unknown, no testing required.⁵

**Consumer products**

- 140 types of consumer products: Unknown. For most products, no labeling or registration required.⁶
- Liquid hand soap: 43%⁷
- Toothpaste: 7%⁷

*Source: Sutton, 2008*
1974 Tentative Final Monograph (TFM)
Evidence lacking for Triclosan safety and effectiveness

1978 Meeting to discuss effectiveness testing
Claims may be misleading to consumers

1994 Removal of antibacterial soaps from drug category
Proliferation is not a problem

1997 Recommended surveillance system for drug resistance

2005 FDA meeting to finalize "tentative final monograph"

2011 Congressional briefing on TCS (Halden, Aiello, Vikesland)
No proven benefit / Known human health & env. risks

Now After 37 years, TFM still not finalized
Prioritized Human Health Risks at a Glance

Triclosan

- Degrades (including chloroform)
- Impurities
- Persistent Environmental Contaminant

Air Pollution with Dioxins

Endocrine Disruption

Cross-resistance to Antibiotics

Bioaccumulation

Halden (2011) Congressional Briefing
• Triclosan persists in the environment
• Ubiquitous contamination threatens some biota
• **Current use of antimicrobials is unsustainable**
• Exposure is certain – Risks are less well understood
• **Current regulations are ineffective**
• Ban of antimicrobials is feasible (e.g., hexachlorophene in 1970s)
• **Removal of TCS & TCC from personal care products would cut the loading of PPCPs to soils by >60%!**
• **Endocrine disruption, multi-drug resistance and air pollution drive risk & require more attention/research/regulation**
General Conclusions: Change Approach to Chemical Management

Don’t:

• Wait
• Regulate compounds one by one
• Replace one type of organohalogen with another

Do:

• Regulate classes of compounds
• Consider degradability
• Engage the chemical manufacturing industry
• Take action now

Halden (2011) Presentation to EPA Emerging Chemicals Workgroup
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