The Fates and Impact of Triclosan in the Environment

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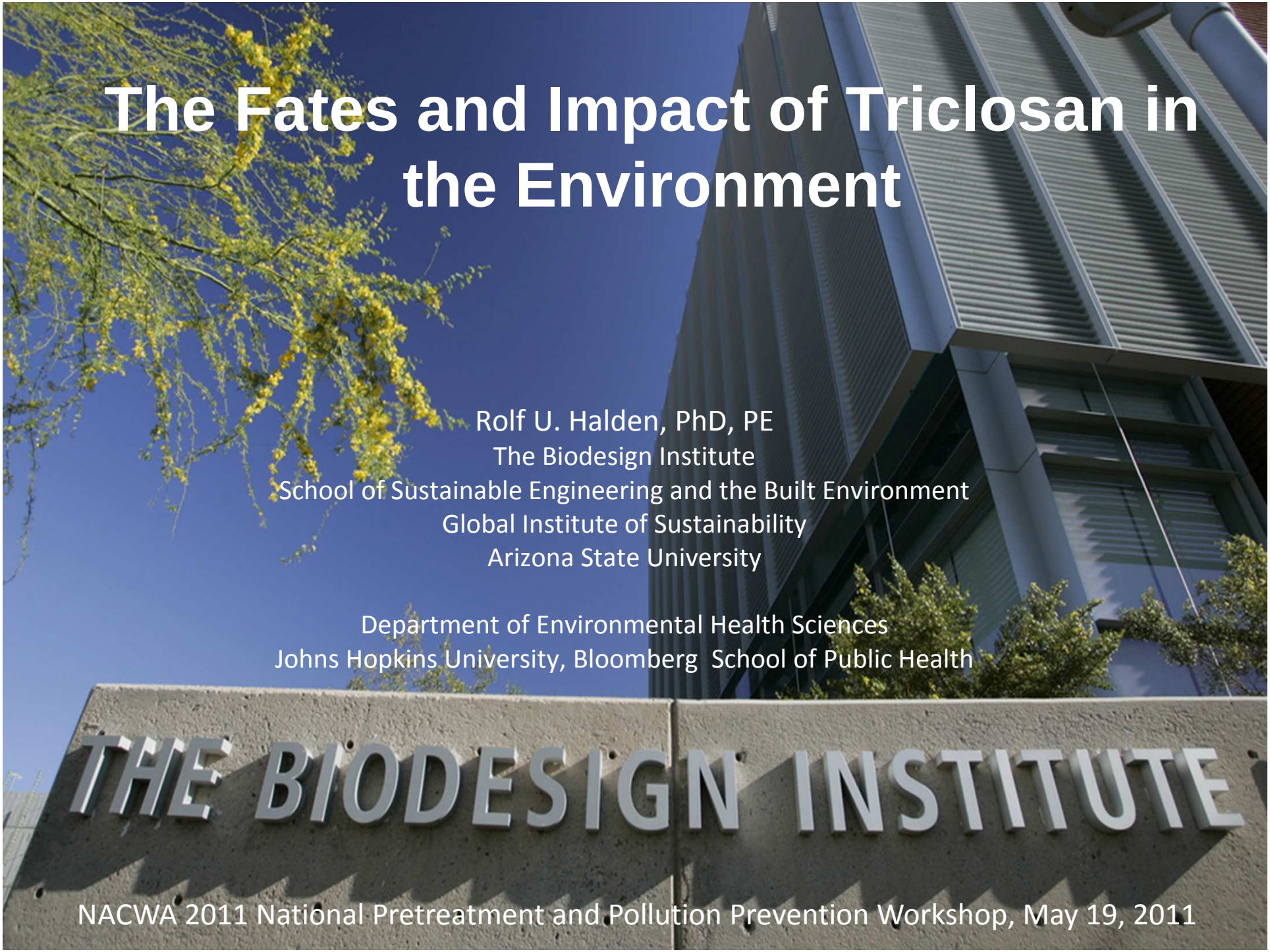


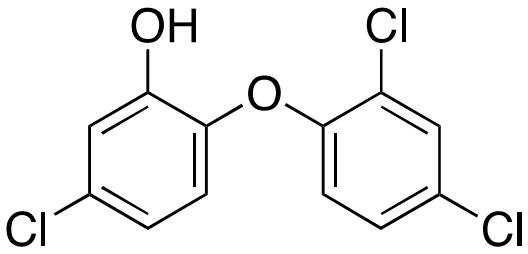
NACWA 2011 National Pretreatment and Pollution Prevention Workshop, May 19, 2011

This presentation contains information from three prior talks:

(1) Halden, RU: 2011 Sustainable Chemistry & Human Health in the 21st Century. U.S. EPA Emerging Chemicals Workgroup, April 6, 2011

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

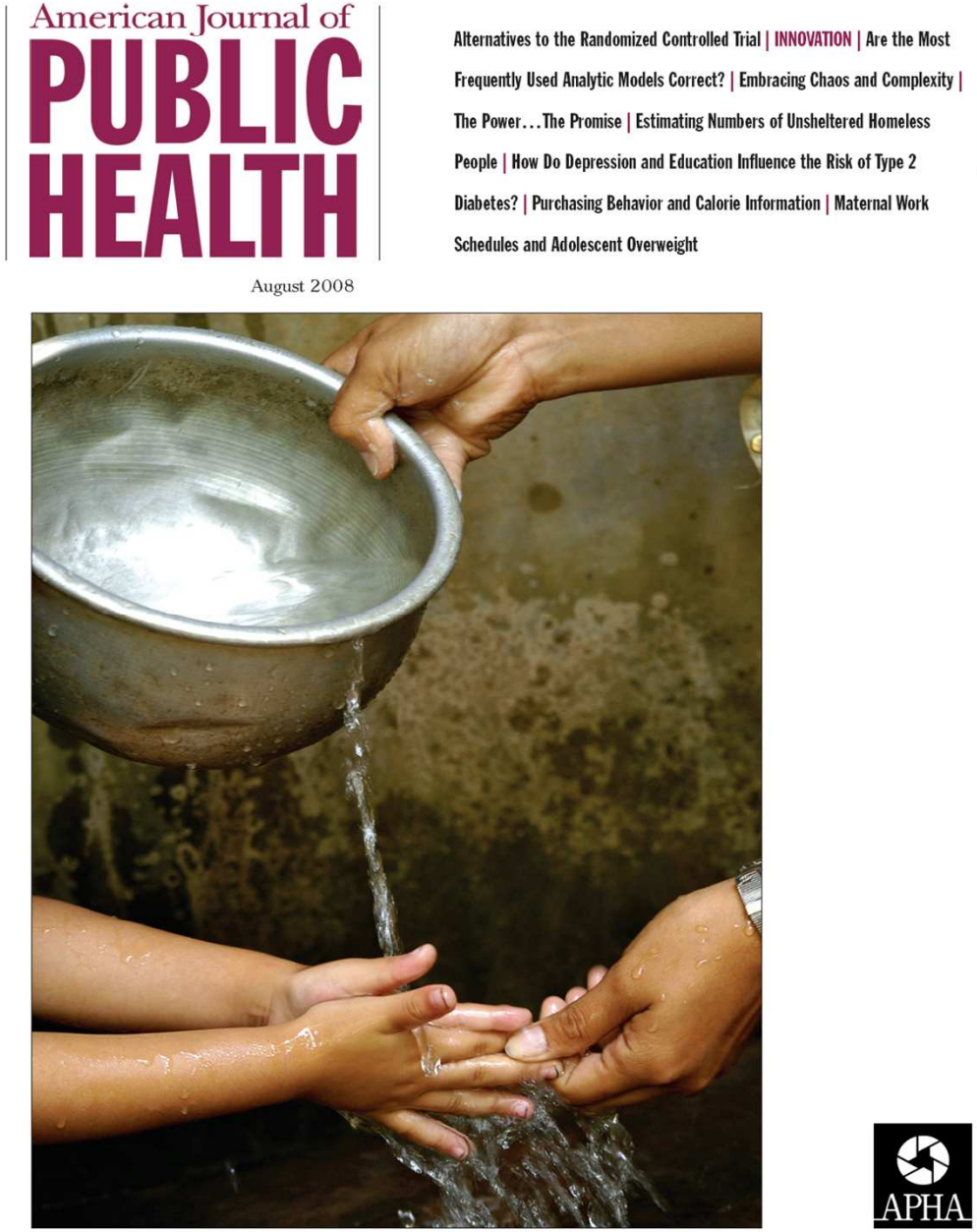
(3) Halden, RU: Congressional Briefing on Triclosan, Washington, DC, February 17, 2011



Triclosan (TCS)

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

Aiello, AE, et al. *American Journal of Public Health*. (2008)

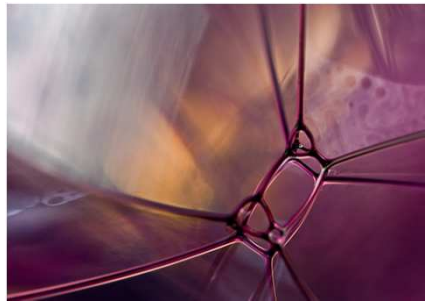
Source: AE Aiello, 2011

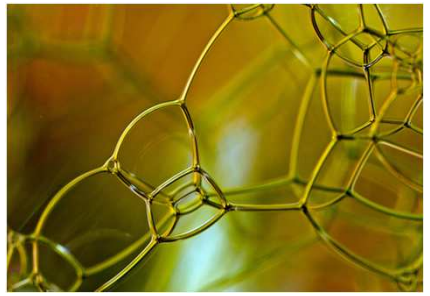
Bacteria/Illness & TCS/TCC

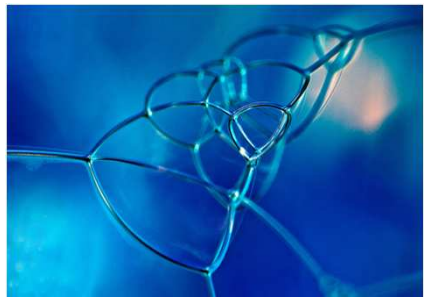
No significant benefit compared to plain soap

- Bacteria
- Illness symptoms

Echoes results of 2005 FDA Panel







Source: AE Aiello, 2011

TCS Susceptibility (Lab)

- 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

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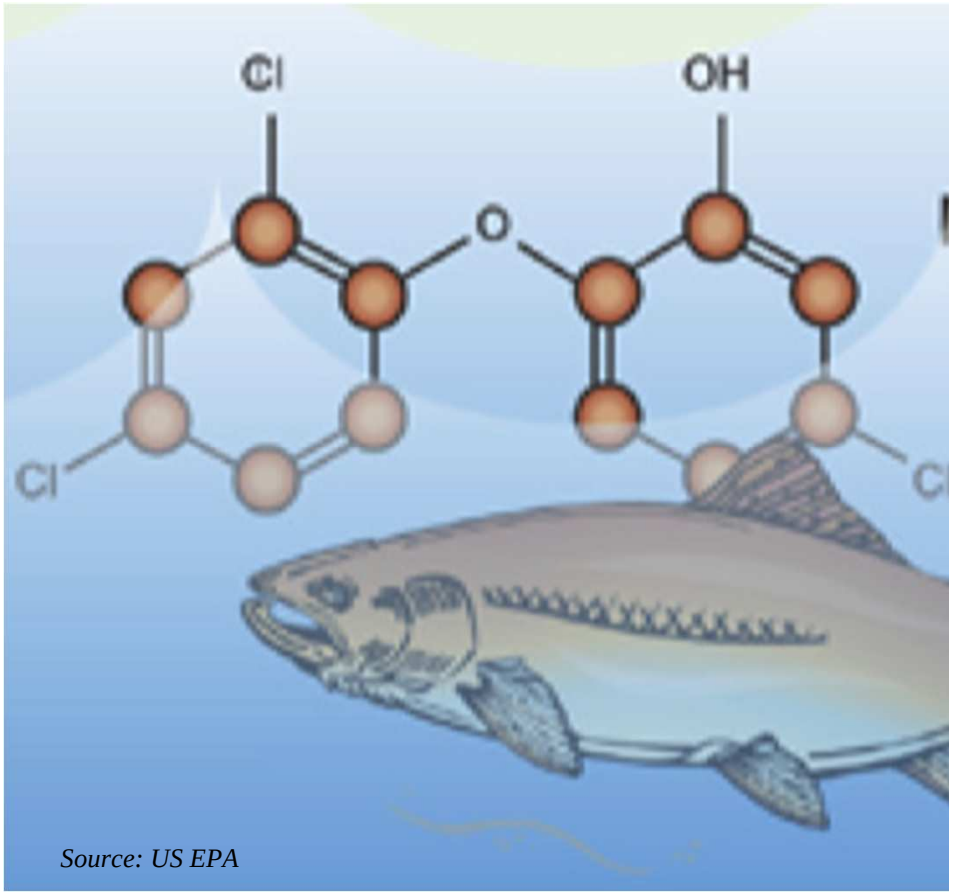
TCS: A Public Health Protection Failure

- 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)



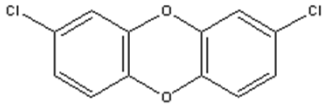
Source: US EPA

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

Known Environmental & Human Health Risks of Triclosan at a Glance

Persistent Environmental Contaminant
✓

Degradates
(including chloroform)



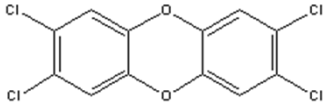
✓

Bioaccumulation
✓

Triclosan

Endocrine Disruption
✓

Impurities

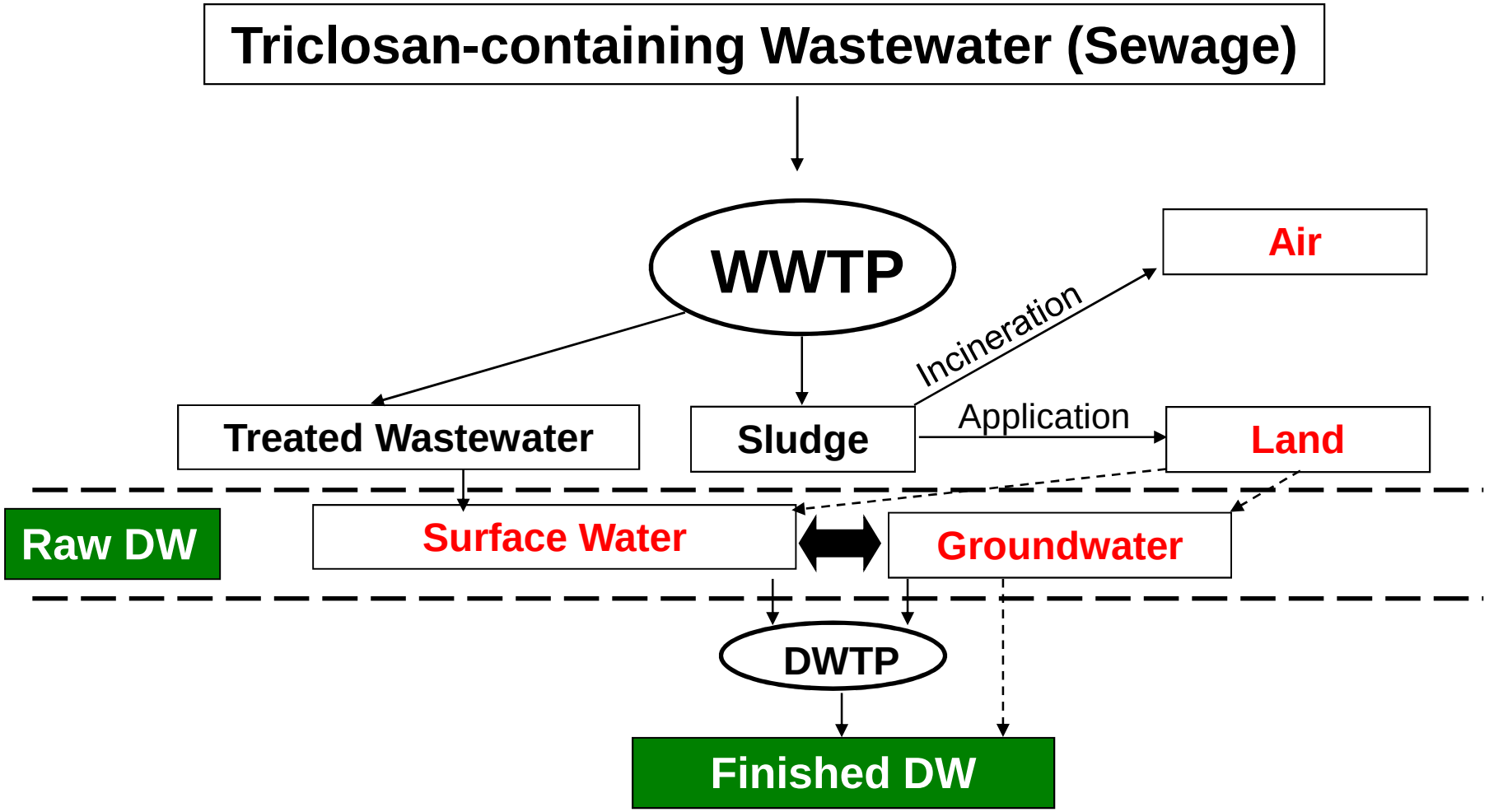


✓

Cross-resistance to Antibiotics
✓

Halden, 2011

Wastewater Treatment Plants (WWTPs) Redistribute Triclosan in the Environment



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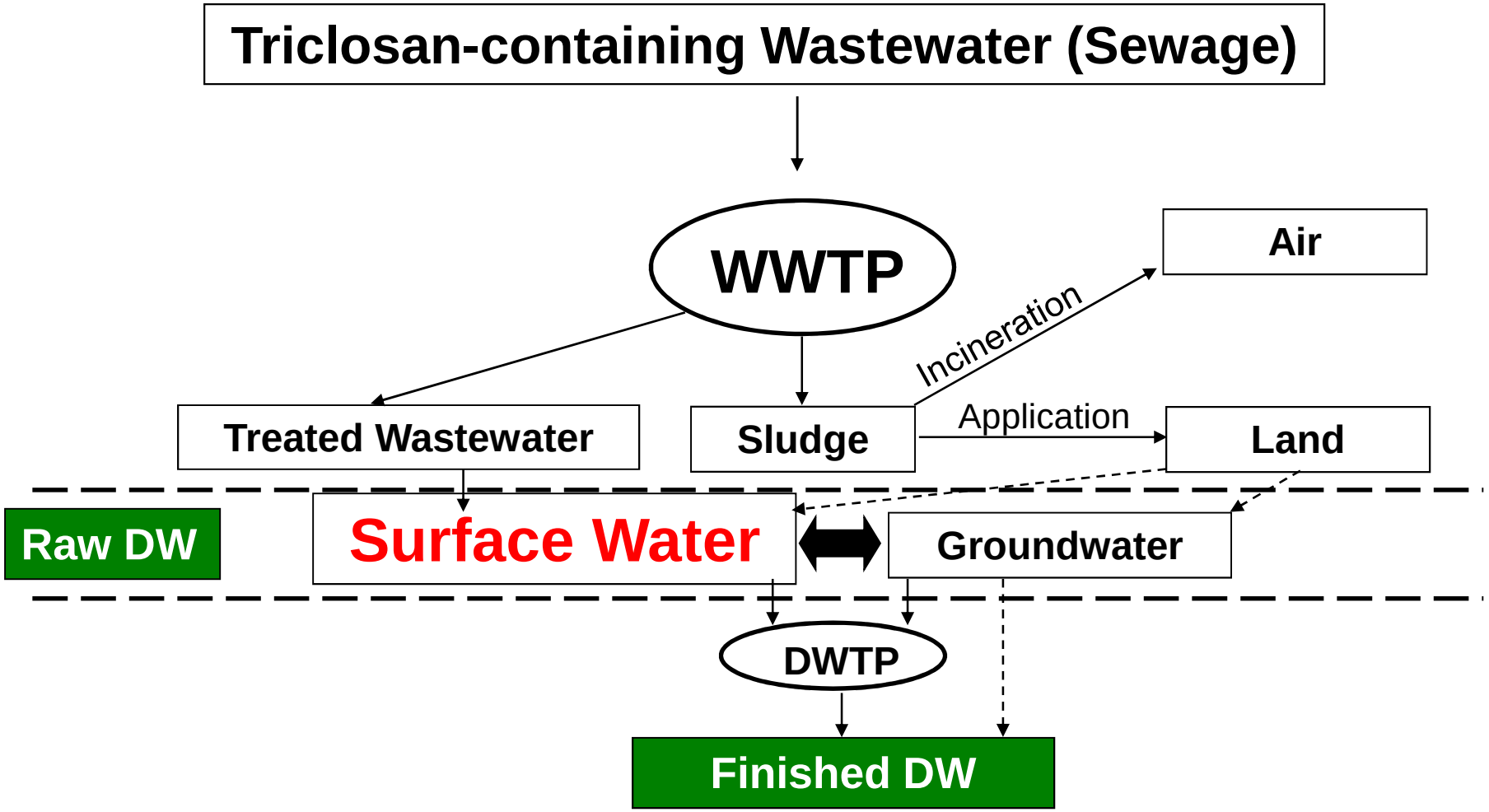
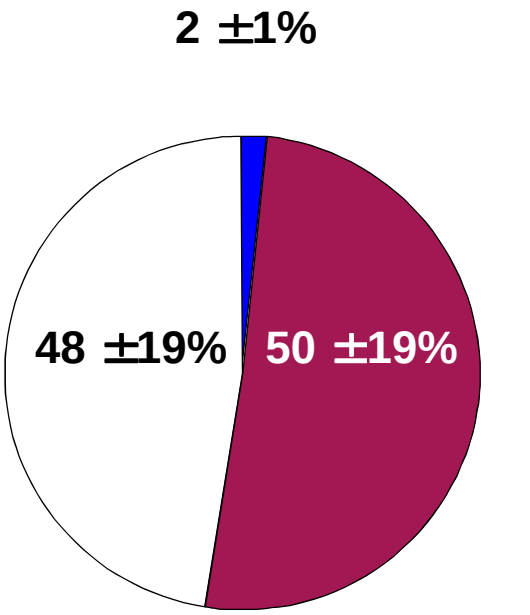
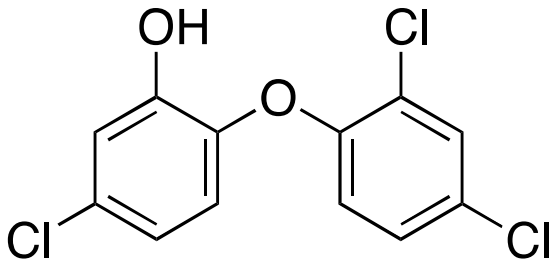



U.S. Wastewater Treatment Plant
Eastern Ave
Island Point Rd
© 2009 Tele Atlas
Google

Fate of Triclosan in Activated Sludge WWTP





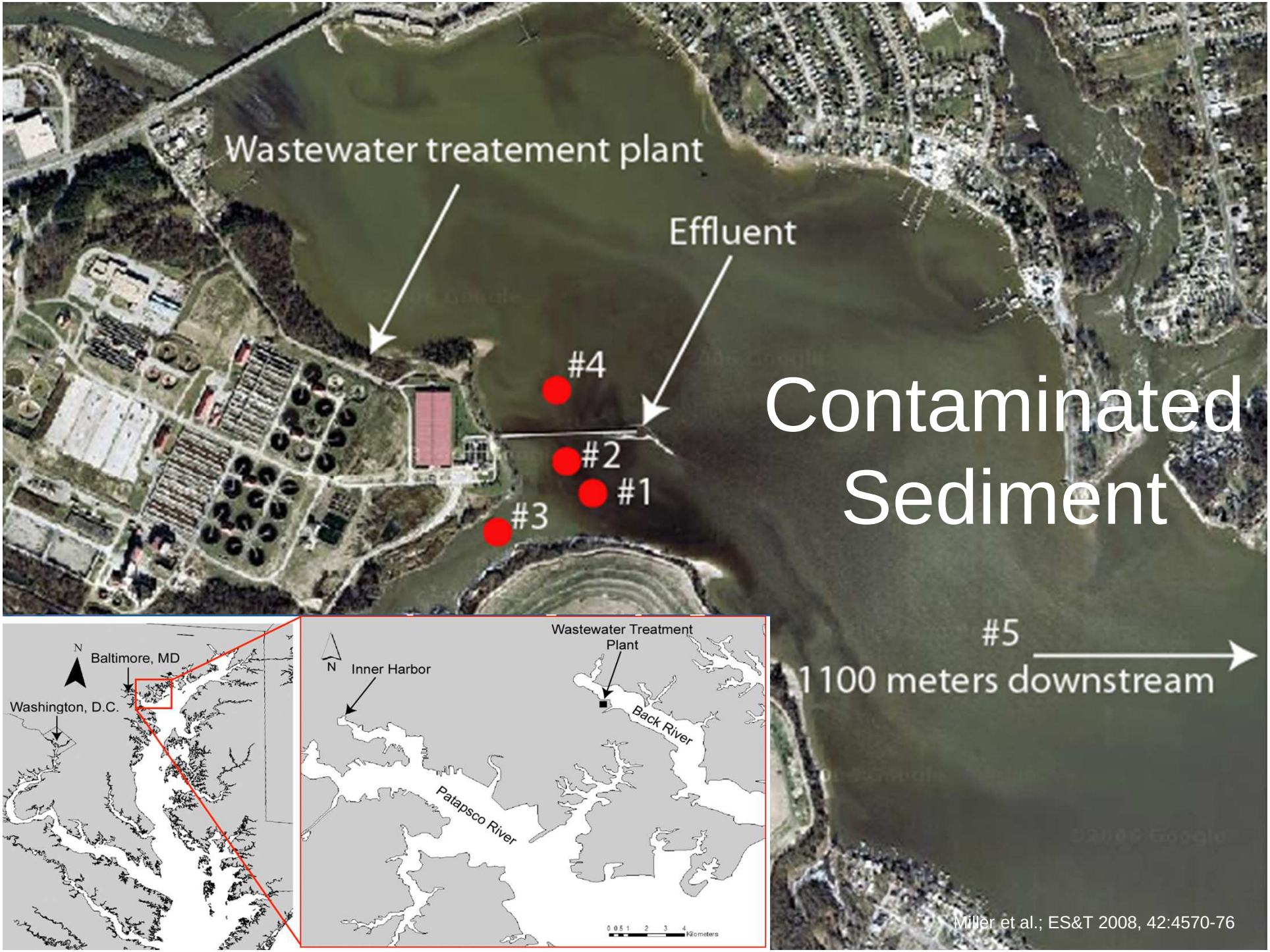
Triclosan (TCS)

Heidler and Halden, Chemosphere 66(2):362-9 (2007)

- 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

Chalew and Halden; J. Am. Water Res. Assoc. 45(1):3-13 (2009)

Source: http://www.dolphinsc.com/images/Dolphin.jpg


Wastewater treatement plant
Effluent
#4
#2
#1
#3
Contaminated Sediment
#5
1100 meters downstream
N
Baltimore, MD
Washington, D.C.
N
Inner Harbor
Wastewater Treatment Plant
Back River
Patapsco River
0 0.5 1 2 3 4 Kilometers
Miller et al.; ES&T 2008, 42:4570-76

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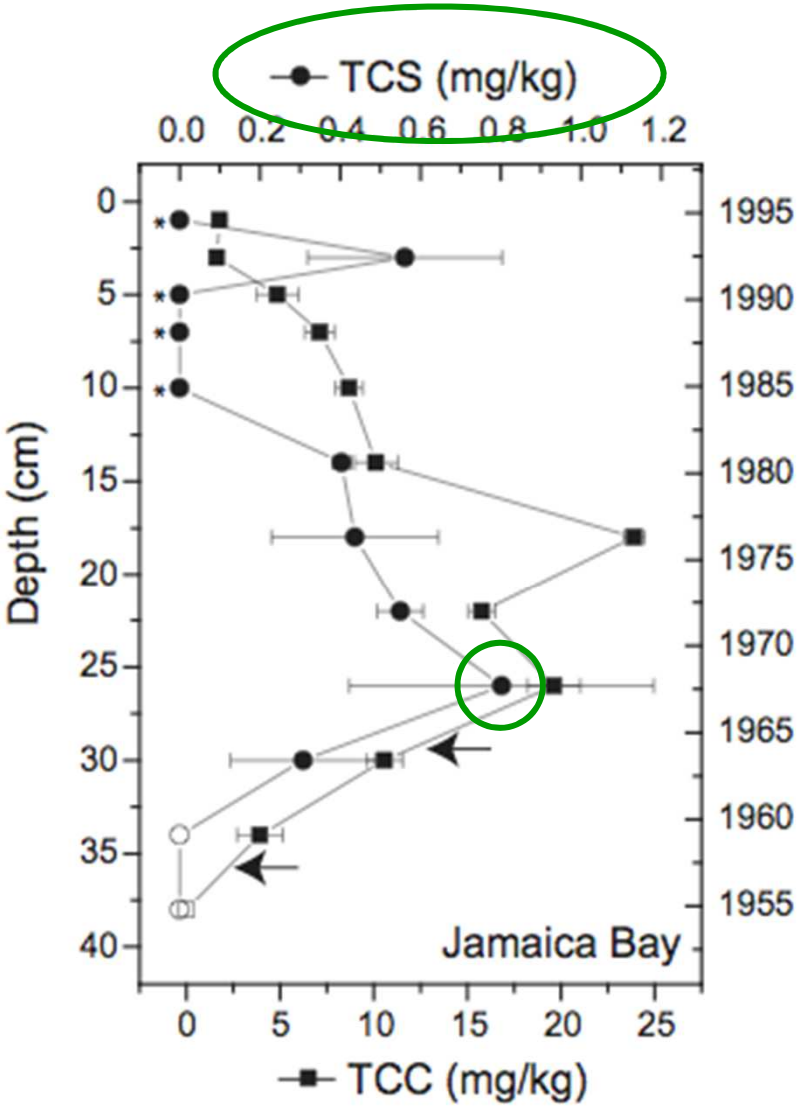
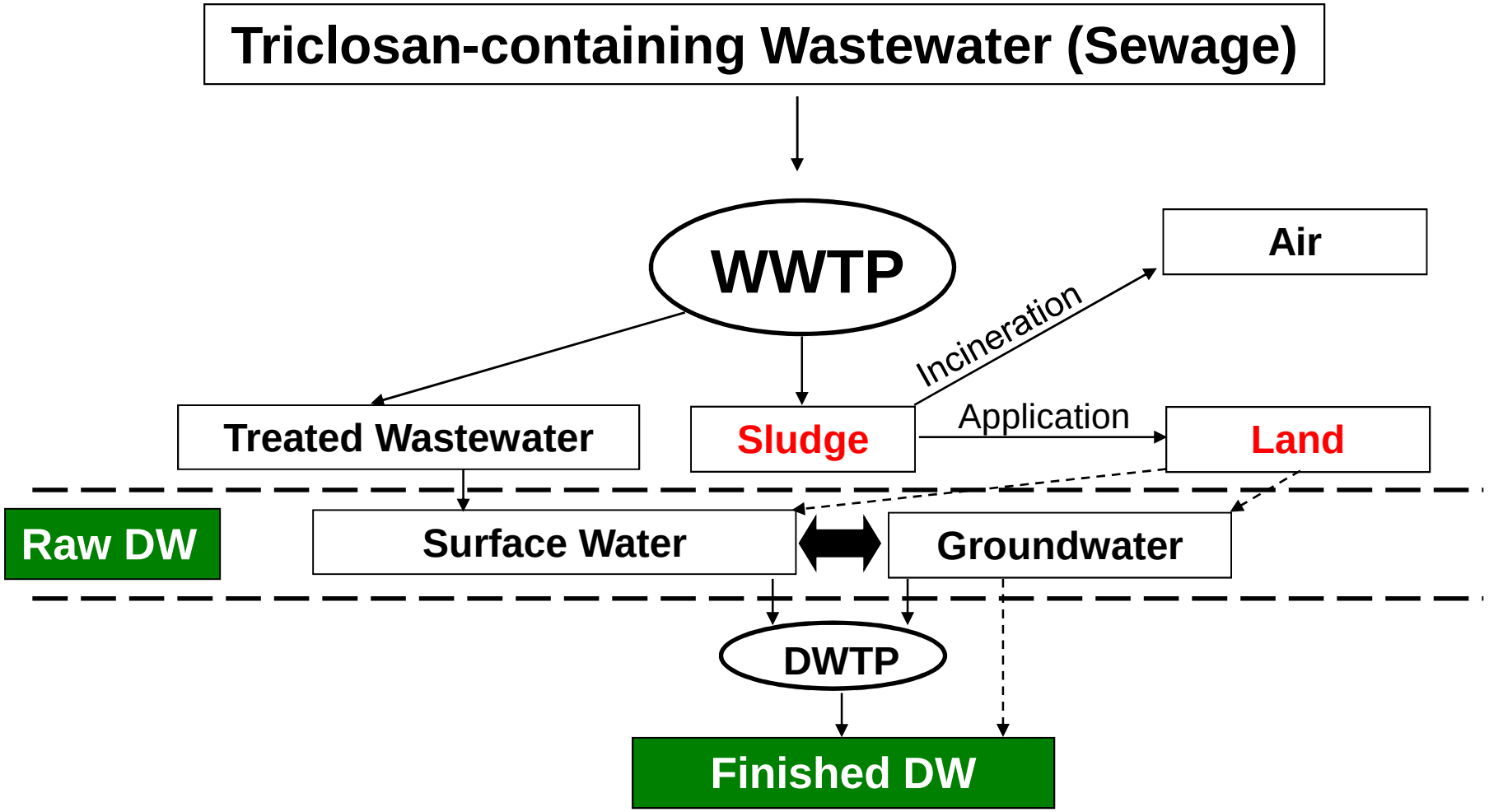
Occurrence of Antimicrobials in Aquatic Sediments



Triclosan used **45 years ago** is still present today in U.S. sediments

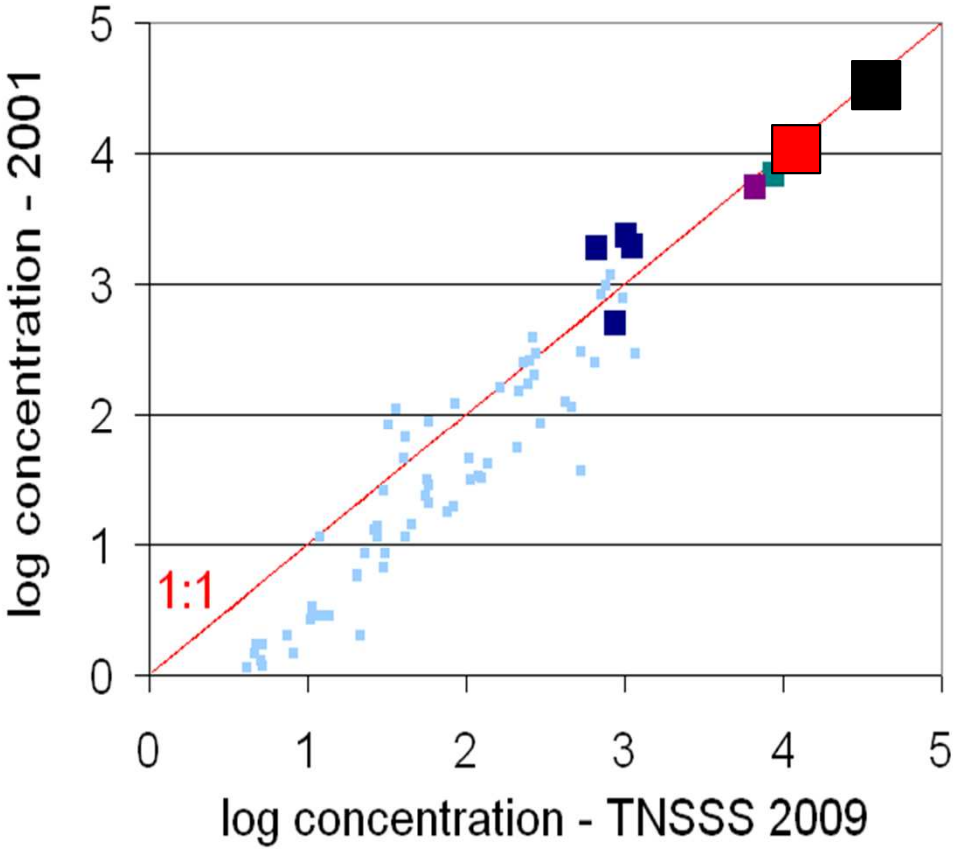
Miller et al. ES&T 2008, 42:4570-76

Wastewater Treatment Plants (WWTPs) Redistribute Triclosan in the Environment



U.S. Sewage Sludge Survey

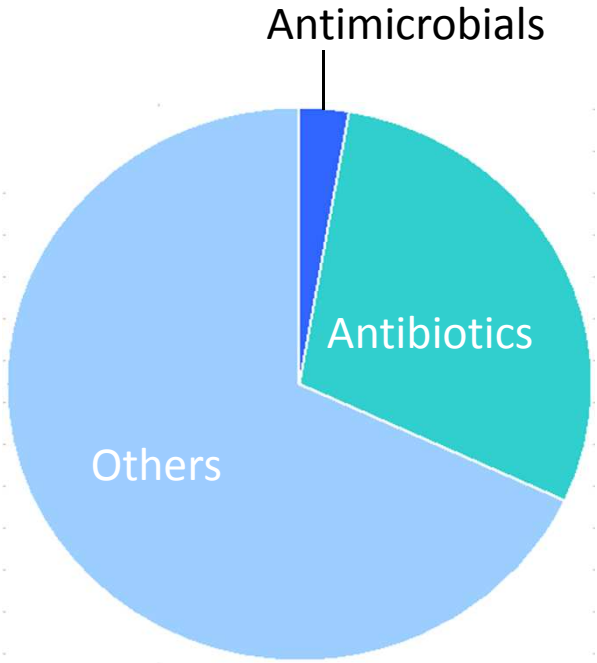
	2009 TNSSS EPA	2001 EPA Samples (ASU)
	Mean concentration [ppm]	
Triclocarban	36	39
Triclosan	12	16
Ciprofloxacin	7	10
Ofloxacin	5	8
Cimetidine, 4-Epitetracycline, Miconazole, Tetracycline	0.5 – 2.5	1 - 2



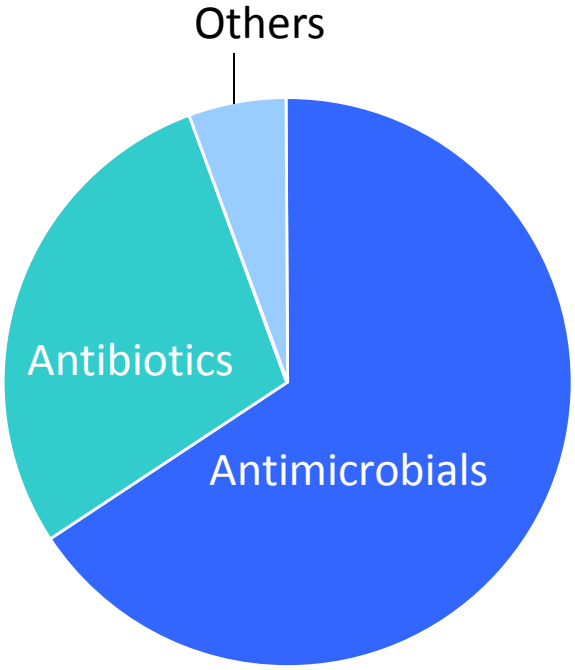
Triclosan and triclocarban are the most abundant PPCPs in sludge

McClellan, Halden; Water Res. 44(2): 658-668 (2010)

TCS & TCC: Key Sludge Pollutants



Compounds



Mass

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

McClellan, Halden; Water Res. 44(2): 658-668 (2010)

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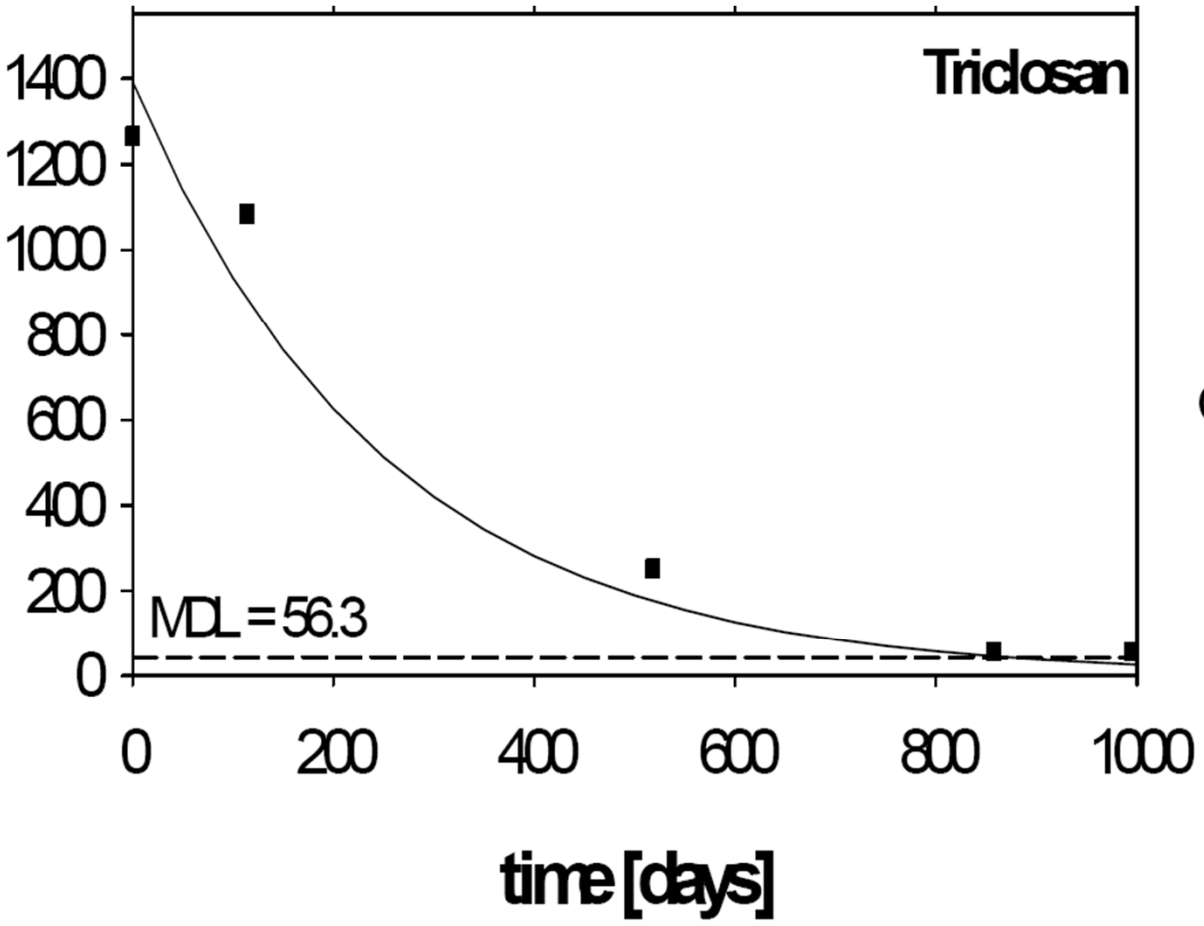
Contaminated Land

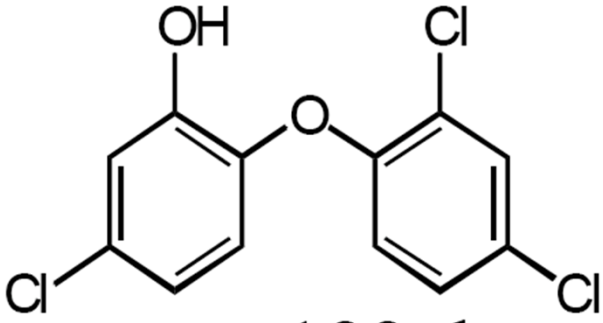
Approximately 140,000 lbs/yr of **Triclosan** and **290,000 lbs/yr** of **Triclocarban** are applied inadvertantly on U.S. agricultural land as a result of sewage sludge disposal

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

Heidler and Halden, J. Environ. Monit. 11:2207-2215 (2009)

Triclosan Exhibits Half-life of 0.5 Years in Agricultural Soil





$t_{1/2} = 188$ d

$R^2 = 0.98$

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

Walters, McClellan, Halden; Water Res. 44: 6011-6020 (2010)

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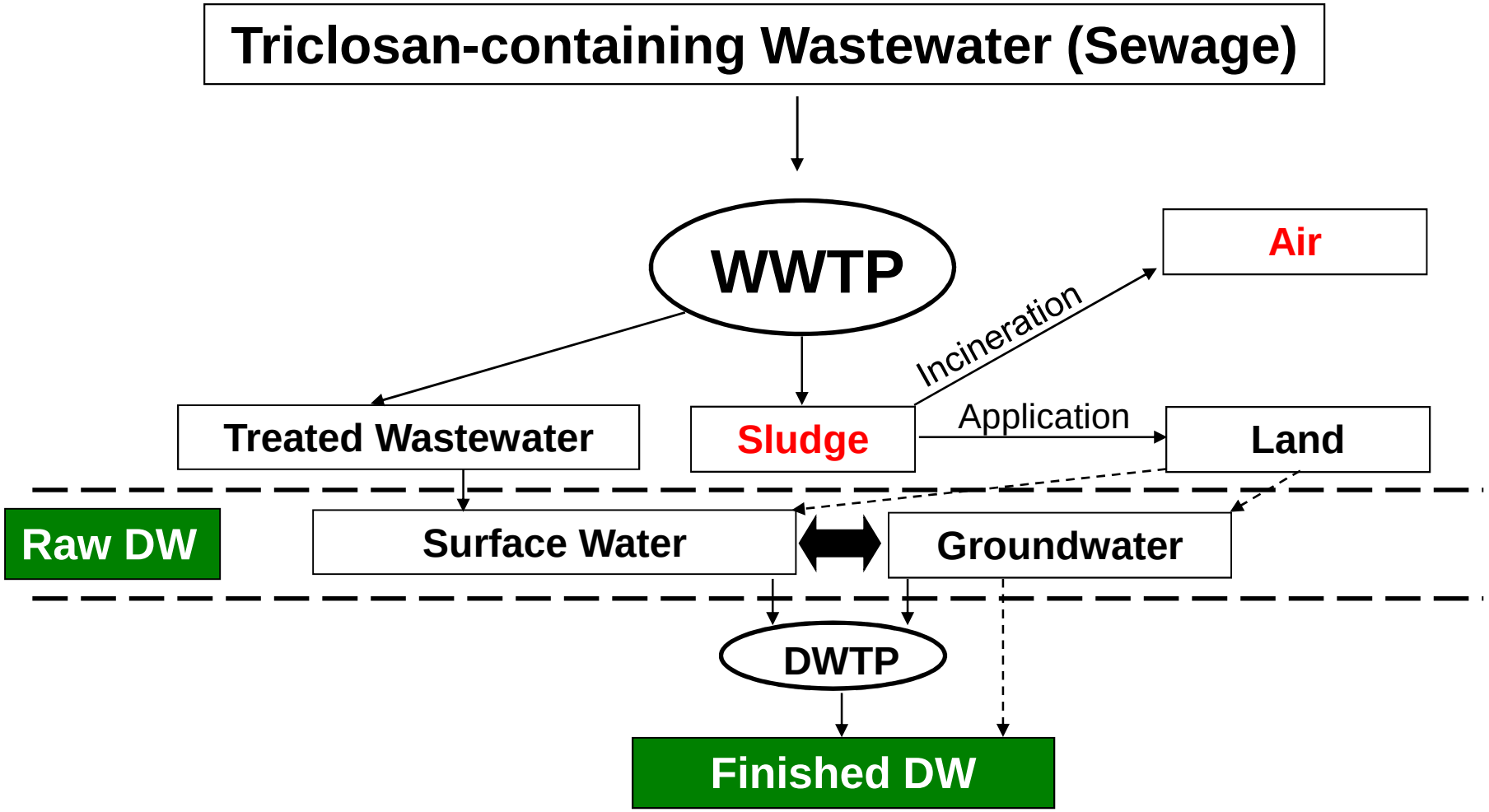
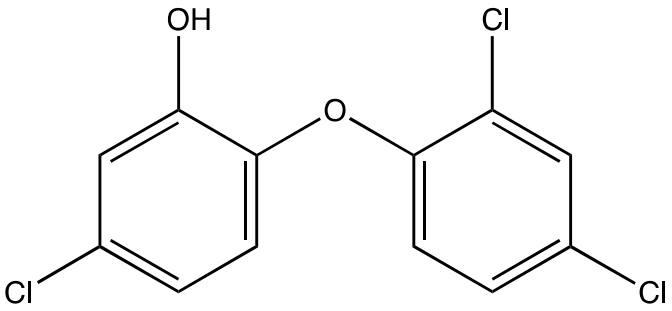
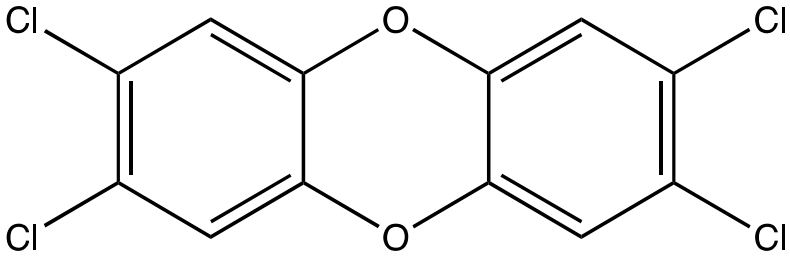


The Dioxin Link

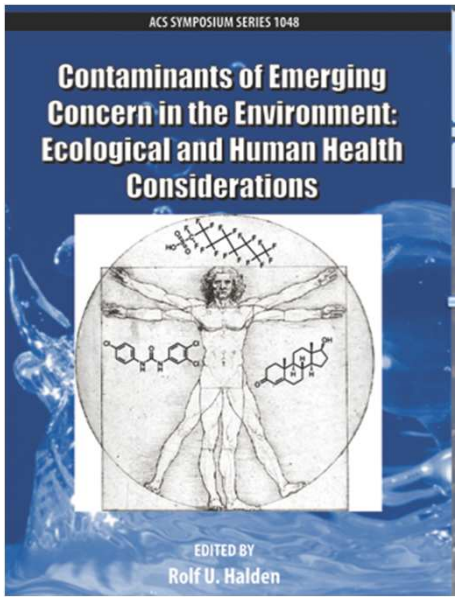
Triclosan (TCS)



Toxic Dioxin (TCDD)



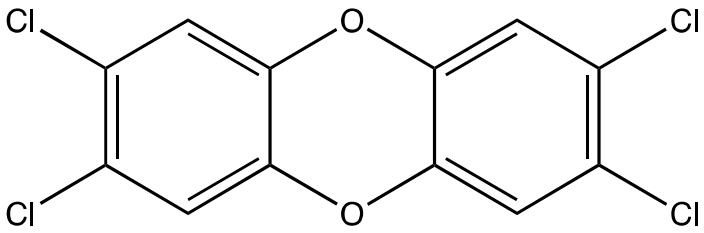
Traces of toxic dioxin (TCDD) are present in commercial grade triclosan and additional dioxins can form during incineration



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

Contaminated Air

Triclosan is a Precursor of Carcinogenic Dioxins



http://oldweb.northampton.ac.uk/aps/env/Wasteresource/1999/Mar99/99mar41.jpg

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)

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

Regulations

- 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 m^3/kg sludge, this is equivalent to 0.86 ng TEQ/dscm
- **3 Times** the lowest standard for other incinerators!

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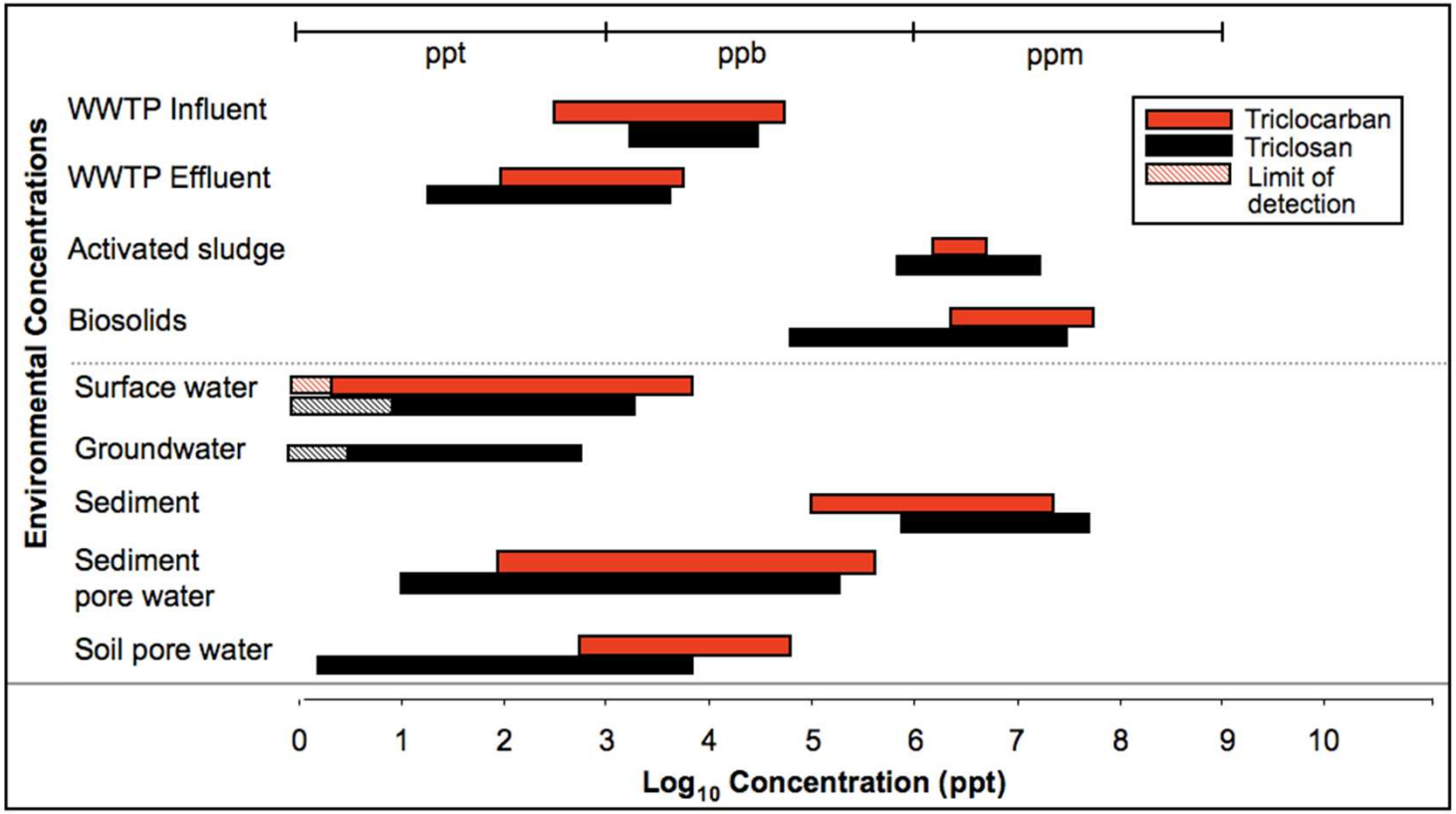
Environmental Occurrences



Chalew and Halden; J. Am. Water Res. Assoc. 45(1):3-13 (2009)

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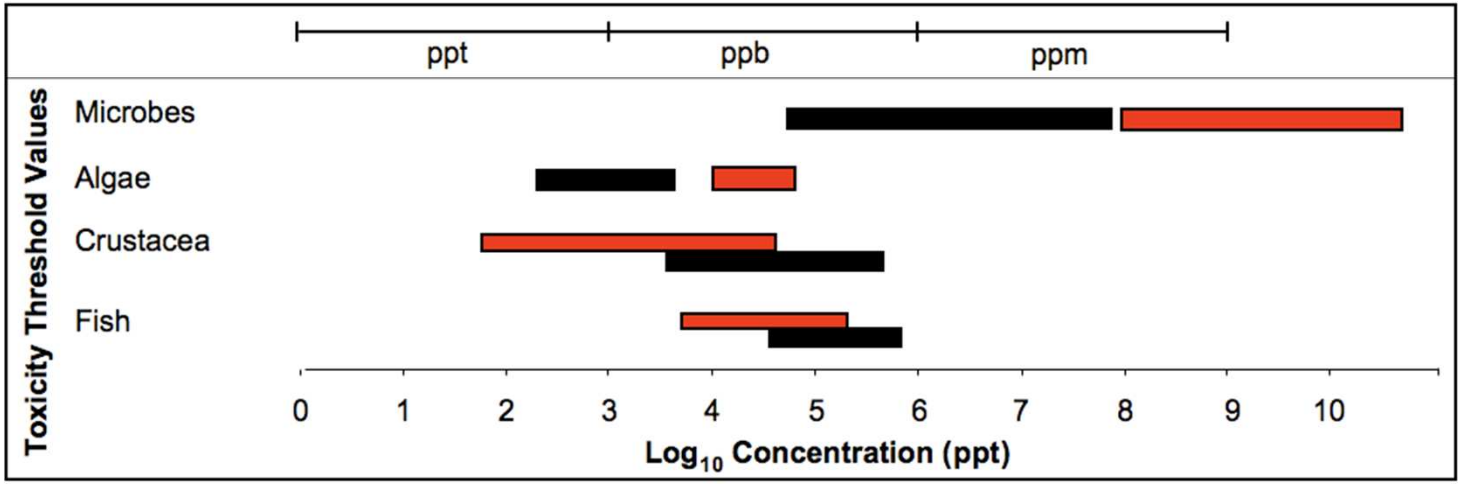
Toxic Threshold Values



Chalew and Halden; J. Am. Water Res. Assoc. 45(1):3-13 (2009)

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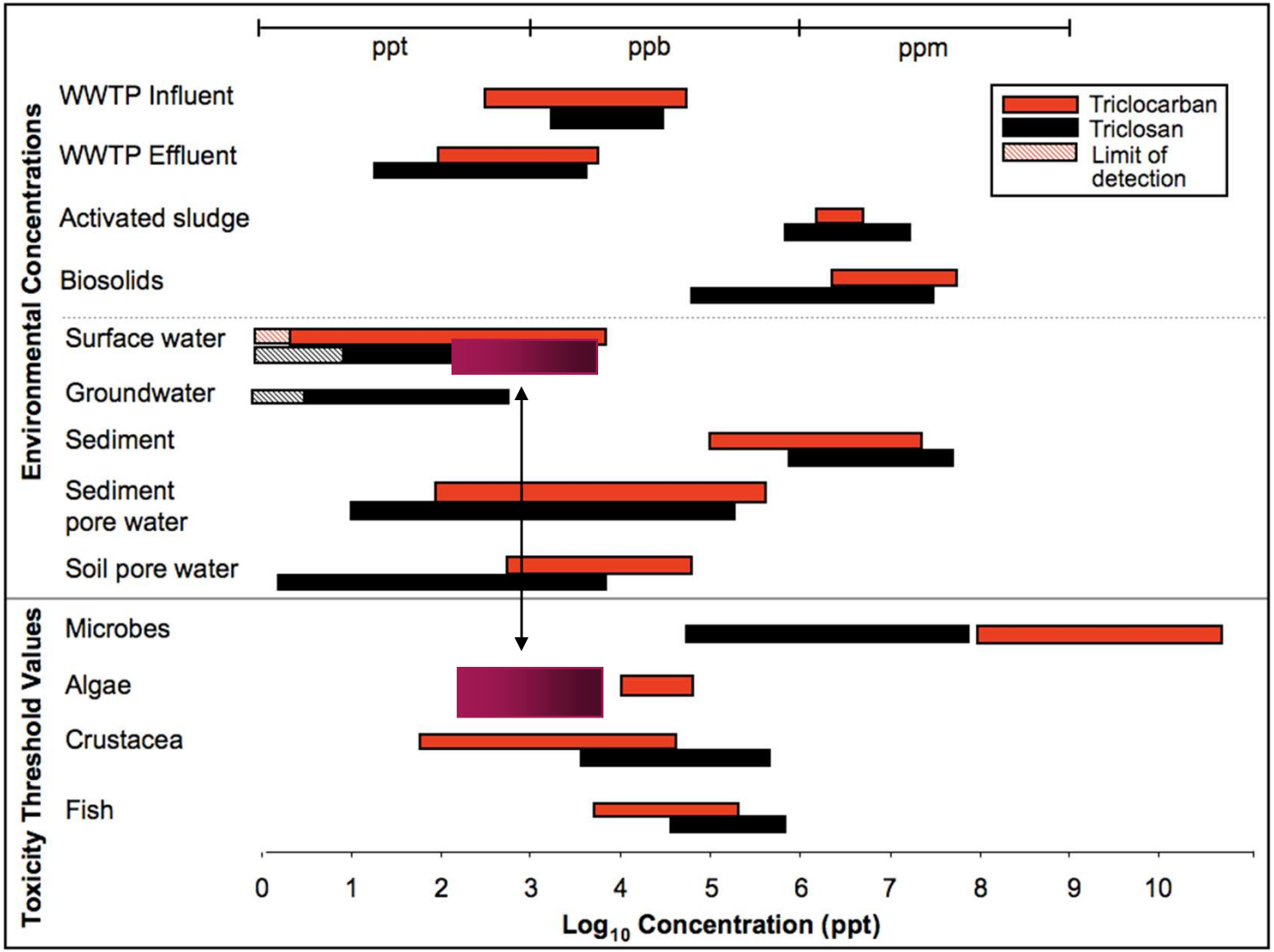
Toxic Levels: Algae in Surface Waters (Triclosan)



Chalew and Halden; J. Am. Water Res. Assoc. 45(1):3-13 (2009)

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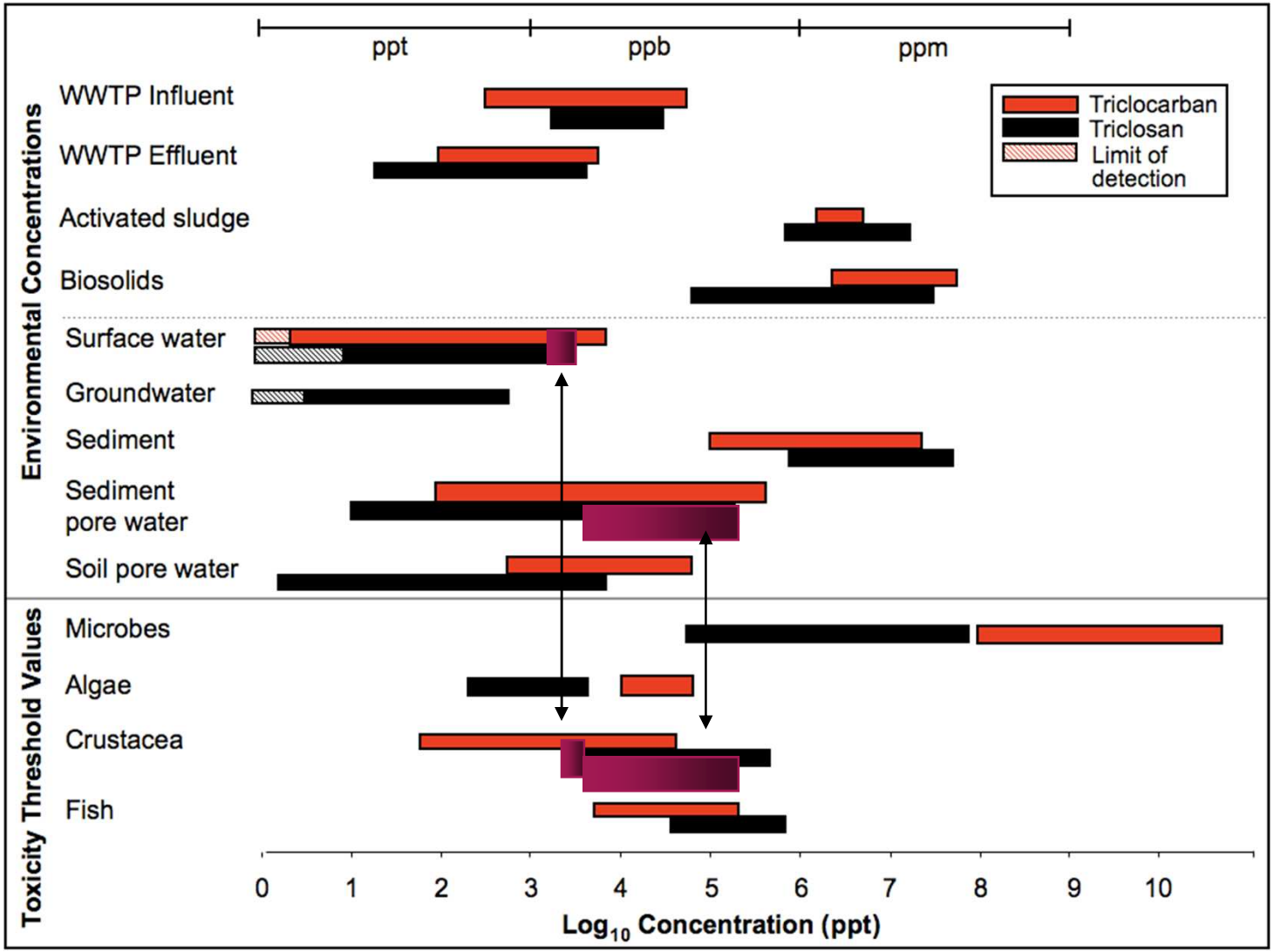
Near-Toxic and Toxic Levels for Crustaceans: Triclosan in Surface Water and Sediment Pore Water



Chalew and Halden; J. Am. Water Res. Assoc. 45(1):3-13 (2009)

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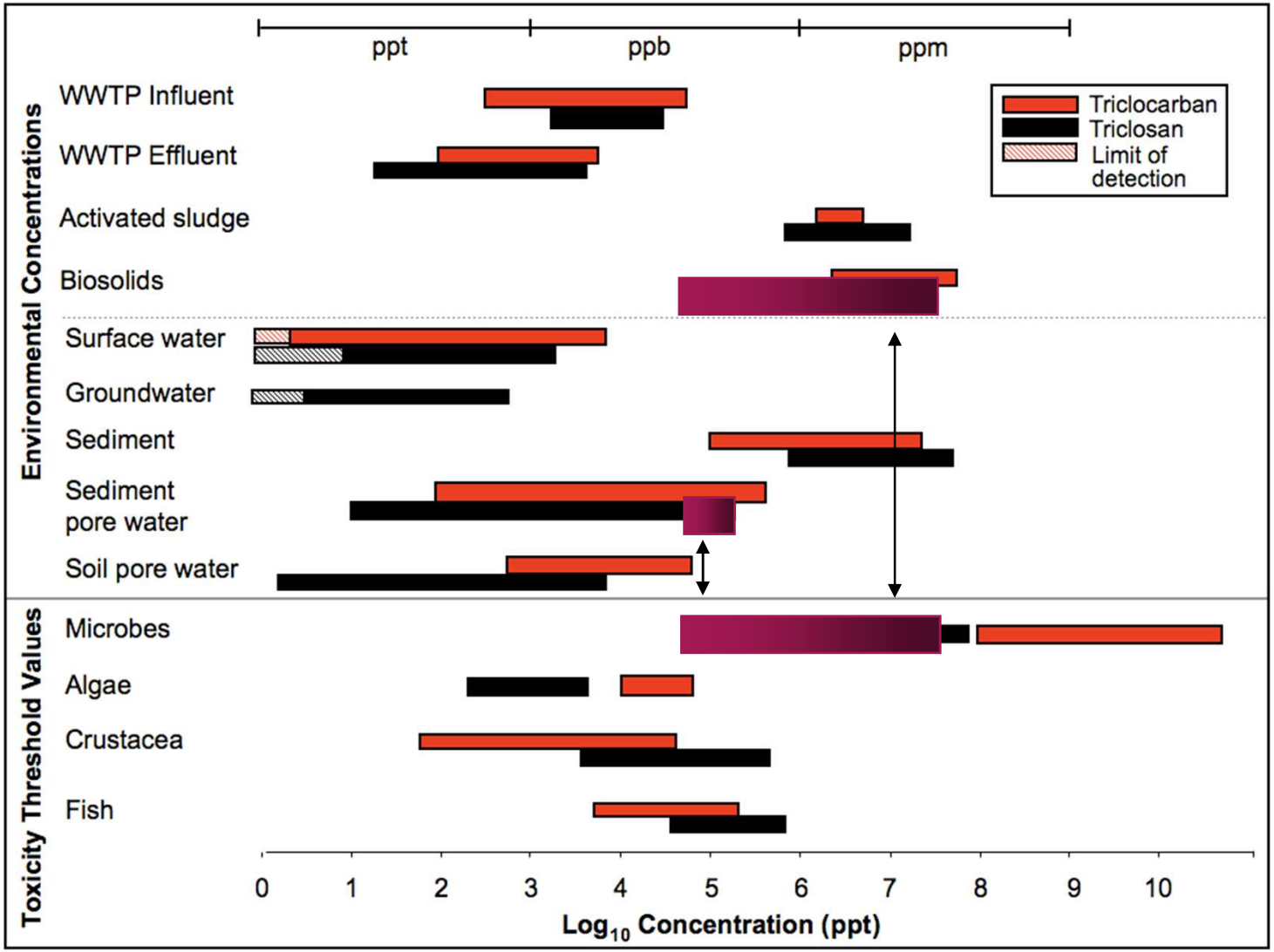
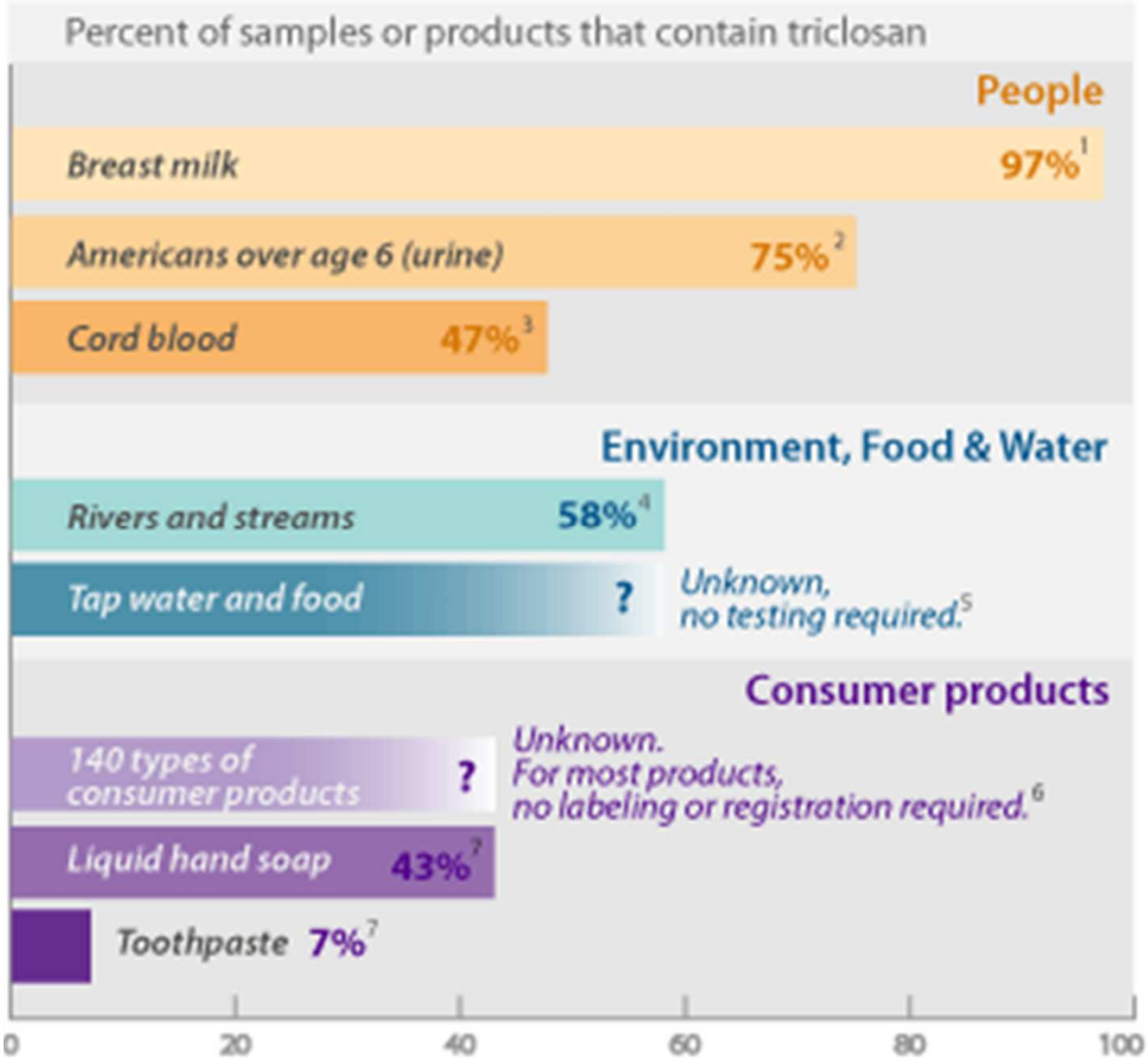
Toxic Levels for Microbes: Triclosan in Sediment & Biosolids



Chalew and Halden; J. Am. Water Res. Assoc. 45(1):3-13 (2009)

Human Exposure & Health Risks



Source: Sutton, 2008

Timeline of TCS Regulation by FDA

1974 **Tentative** Final Monograph (TFM)
Evidence lacking for Triclosan safety and effectiveness

1978 Meeting ot 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

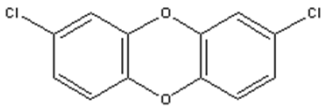
2005 FDA meeting to finalize "tentative final monograph"

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

Degradates
(including chloroform)

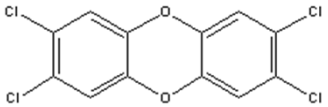


✓

Persistent Environmental Contaminant
✓

Cross-resistance to Antibiotics
✓

Impurities



✓

Triclosan

Bioaccumulation
✓

Air Pollution with Dioxins
✓

Endocrine Disruption
✓

Halden (2011) Congressional Briefing

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Conclusions

- 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

Acknowledgements

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Erica Hartmann
Tomasz Kalinowski
Darryl Jones
Talia Chalew

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