

# Considering the Microbial Loop in Wildlife Conservation

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Johns Hopkins University

Center for Water and Health

*Rachel Carson Centennial Celebration*

*USGS Patuxent Wildlife Research Center, Laurel, MD*

*May 18, 2007*

# Polyhalogenated Organics

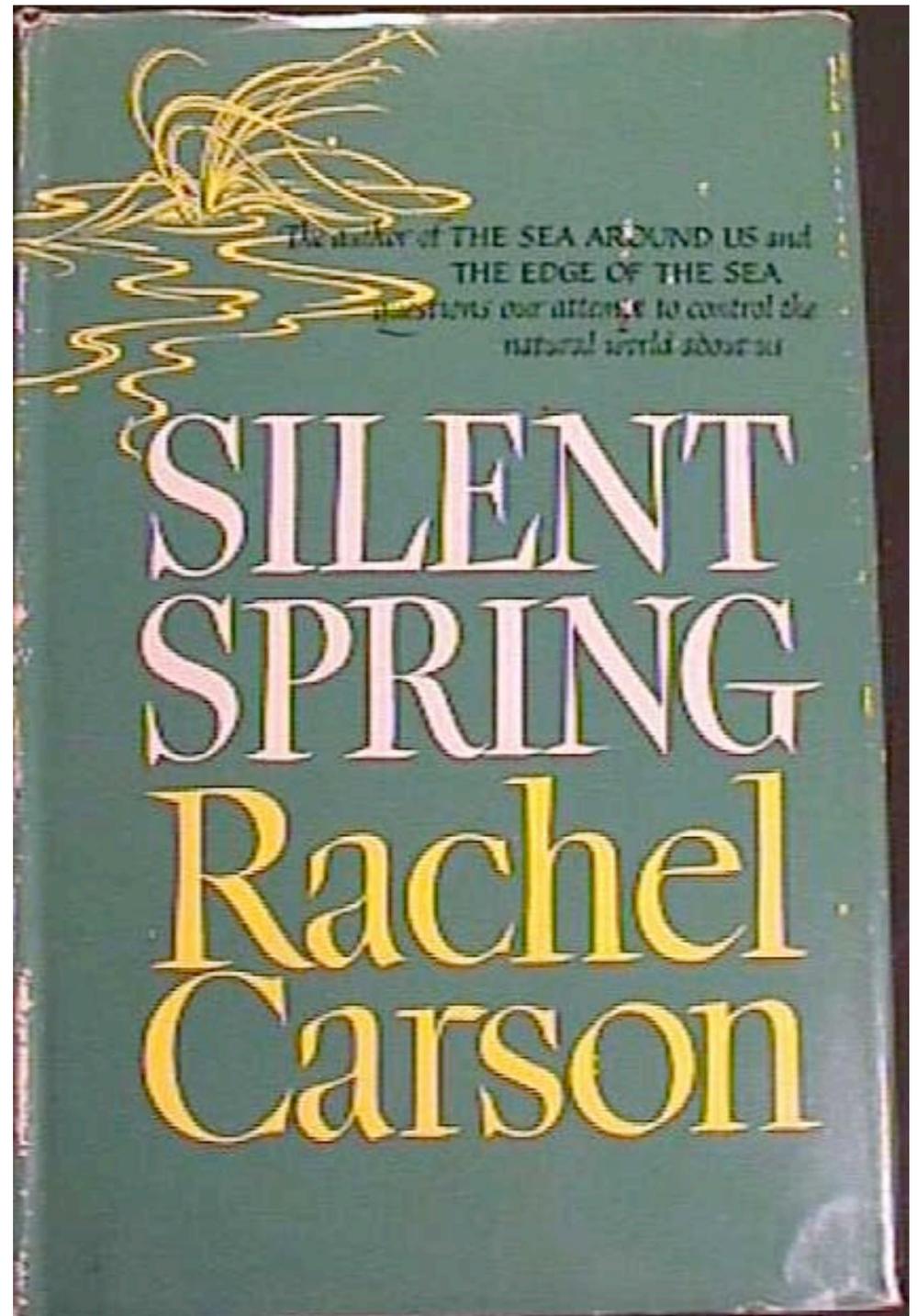
Past and future of a problematic group of chemicals

endangering people, birds and microorganisms alike.

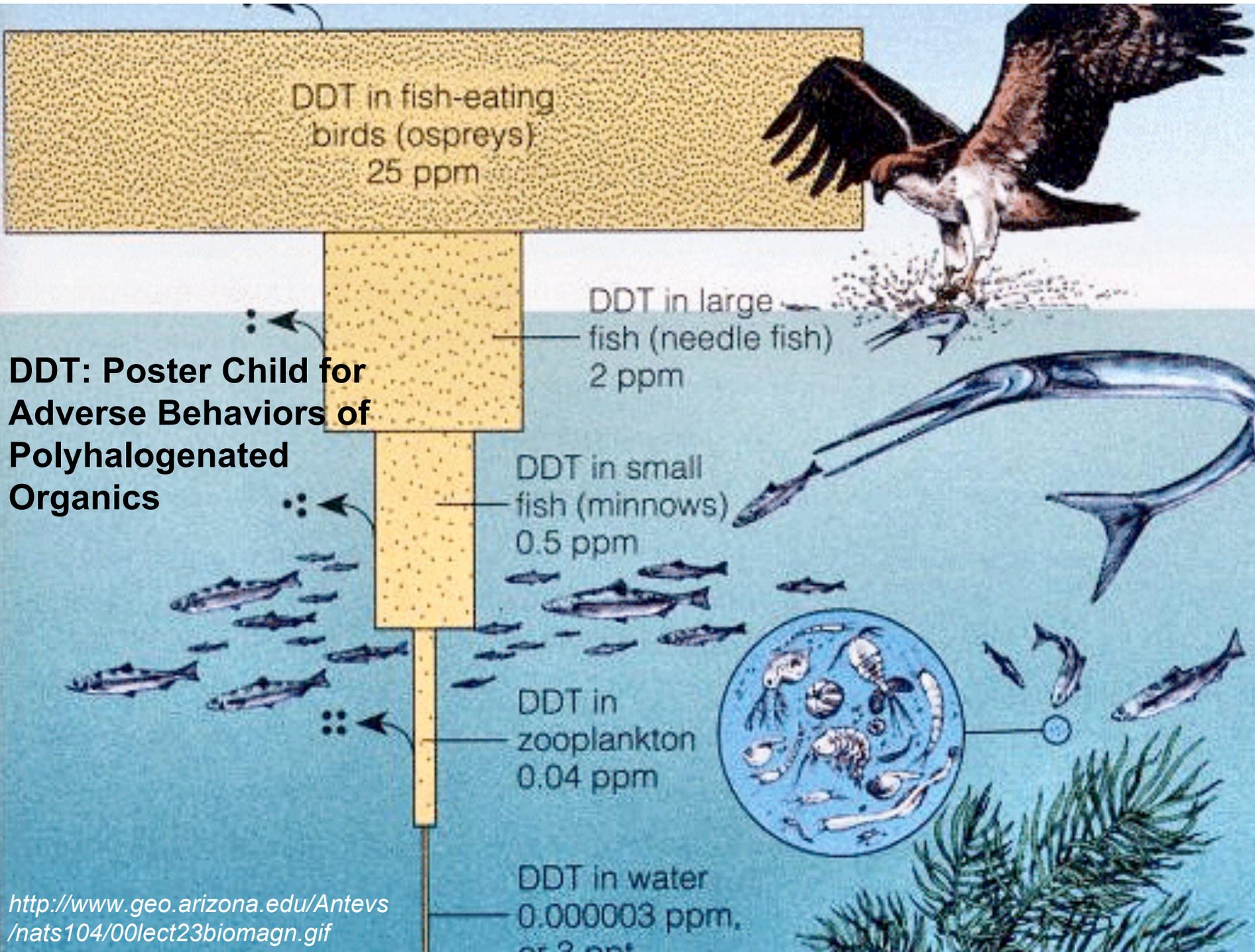
# 1962: Voicing Doubts Based on Little Data



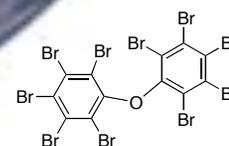
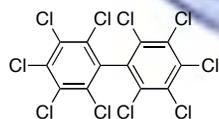
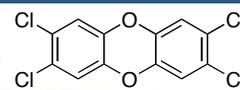
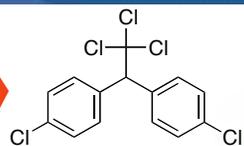
**1962: A Book Changes the  
Political and Environmental  
Landscape**

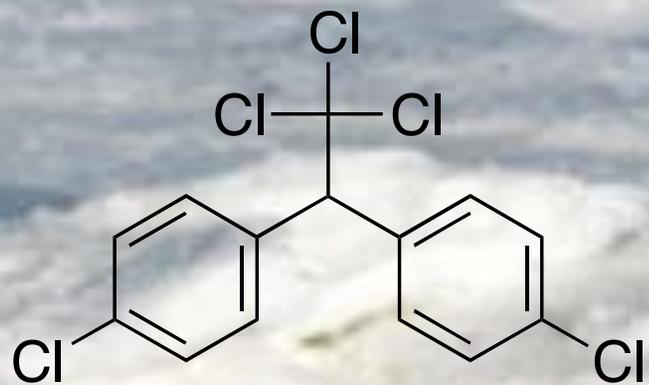


**DDT: Poster Child for Adverse Behaviors of Polyhalogenated Organics**

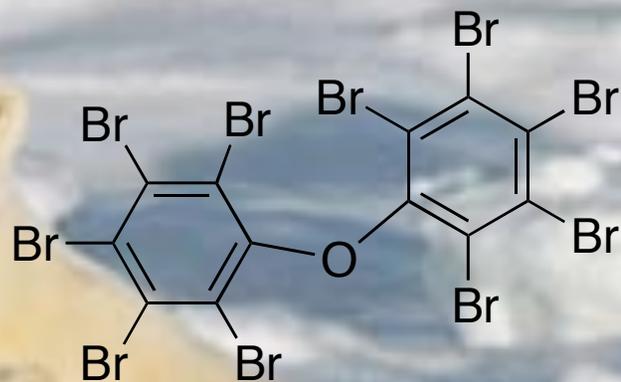


# Global Transport of Pollutants

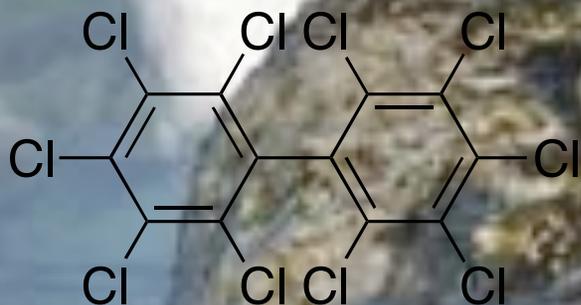




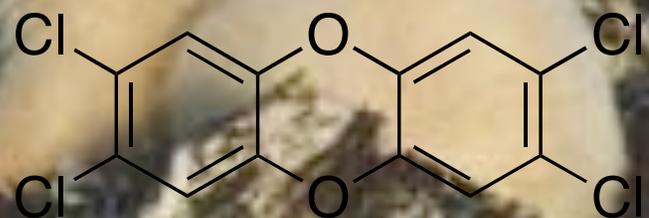
**DDT**



**PBDE**



**PCB**



**Dioxin**

## Today's Chemosphere

- Actual number of chemicals is unknown ( $\Rightarrow \infty$ )
- 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
- Are pesticides still important pollutants?

# Extracting Knowledge from the Safe Drinking Water Act (SDWA): What's Regulated?



Drinking Water and Health Basics

Frequently Asked Questions

Local Drinking Water Information

Drinking Water Standards

List of Contaminants & MCLs

Regulations & Guidance

Public Drinking Water Systems

Source Water Protection

Underground Injection Control

Data & Databases

Drinking Water Academy

Safe Drinking Water Act

National Drinking Water Advisory Council

Water Infrastructure Security

Drinking Water

## Ground Water & Drinking Water

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[EPA Home](#) > [Water](#) > [Ground Water & Drinking Water](#) > Current Drinking Water Standards

## 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 system 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 K PDF FILE, 1 pg) ([ALL ABOUT PDF FILES](#))
- [National Primary Drinking Water Regulations](#) [EXIT disclaimer](#) - The complete regulations regarding these contaminants available from the Cc

### National Secondary Drinking Water Regulations

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

- [List of National Secondary Drinking Water Regulations](#)
- [National Secondary Drinking Water Regulations](#) [EXIT disclaimer](#) - The complete regulations regarding these contaminants available from the

### Unregulated Contaminants

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

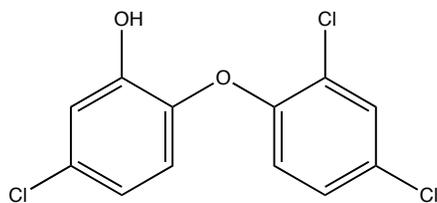
- [List of Unregulated Contaminants](#)
- [Drinking Water Contaminant Candidate List \(CCL\) Web Site](#)
- [Unregulated Contaminant Monitoring Program \(UCM\)](#)

List of Contaminants & their MCLs

# Primary Chemical Contaminants in SDWA

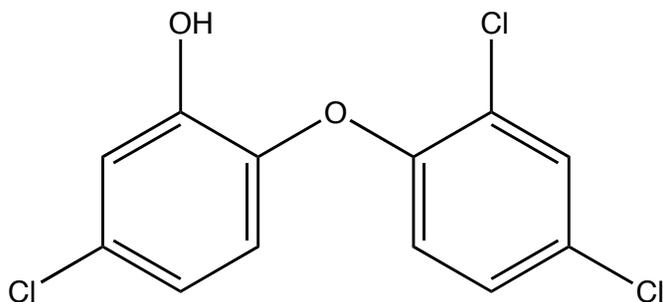
- Chemicals (~80 total)
    - Inorganic compounds (16)
      - Radionuclides (4 types/groups)
      - Elements (14)
    - **Organic compounds (~53)**
      - Non-halogenated compounds (12)
      - Halogenated compounds (~41)
      - Chlorinated compounds (40)
      - Pesticides (~24)
- ⇒ **75% of regulated organic DW contaminants are chlorinated organics**
- ⇒ **45% are pesticides**

# Examining Our Relationship With Nature...

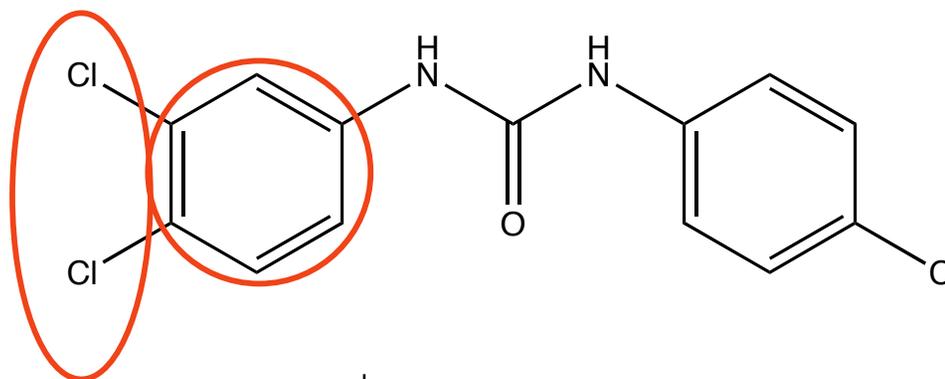


## ...By Entering the Antiseptic World of...

### Triclosan (TCS)



### Triclocarban (TCC)



Name	Triclosan	Triclocarban
Year Introduced	1964	1957
Log $K_{OW}$ (at 25°C, pH 7)	4.8	4.9

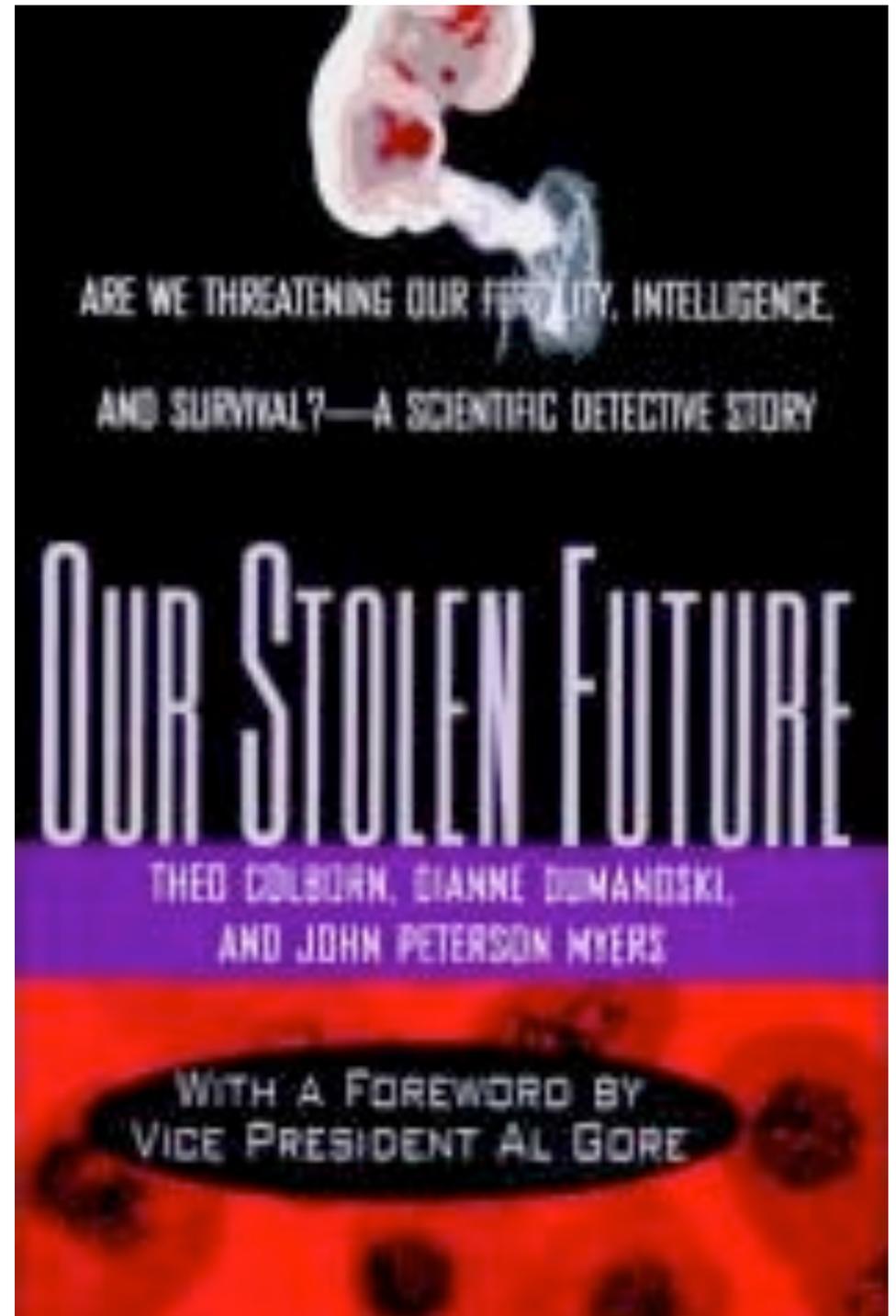
For each molecule in water, there are  $\sim 10^5$  in octanol (fat)

# 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



**1996: Another Book Appears,  
Emphasizing the Risks of  
Endocrine Disruption**



# Antimicrobials: Endocrine Disruption in Frogs



Aquatic Toxicology 80 (2006) 217–227



The bactericidal agent triclosan modulates thyroid hormone-associated gene expression and disrupts postembryonic anuran development

Nik Veldhoen<sup>a</sup>, Rachel C. Skirrow<sup>b</sup>, Heather Osachoff<sup>b</sup>, Heidi Wigmore<sup>b</sup>, David J. Clapson<sup>a</sup>,  
Mark P. Gunderson<sup>a</sup>, Graham Van Aggelen<sup>b</sup>, Caren C. Helbing<sup>a,\*</sup>

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<sup>b</sup> Pacific Environmental Science Centre, 2645 Dollarton Highway, North Vancouver, British Columbia V7H 1V2, Canada

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Cell assay: concentrations of as low as 30 ng/L  
alter thyroid hormone receptor mRNA expression

# Antimicrobials: Endocrine Disruption in Mussels



Available online at [www.sciencedirect.com](http://www.sciencedirect.com)



Comparative Biochemistry and Physiology, Part C 145 (2007) 464–472

**CBP**

[www.elsevier.com/locate/cbpc](http://www.elsevier.com/locate/cbpc)

## Effects of Triclosan on *Mytilus galloprovincialis* hemocyte function and digestive gland enzyme activities: Possible modes of action on non target organisms

Laura Canesi <sup>a,\*</sup>, Caterina Ciacci <sup>b</sup>, Lucia Cecilia Lorusso <sup>b</sup>, Michele Betti <sup>b</sup>,  
Gabriella Gallo <sup>a</sup>, Giulio Pojana <sup>c</sup>, Antonio Marcomini <sup>c</sup>

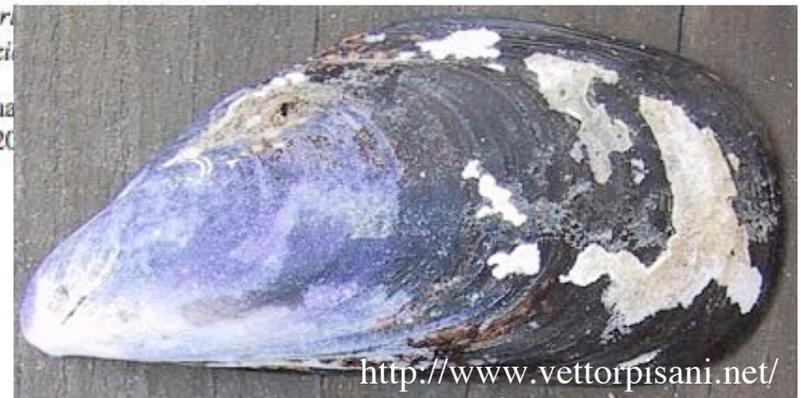
<sup>a</sup> Dipartimento di Biologia, Università di Genova, Corso Europa 26, 16132, Italy

<sup>b</sup> Istituto di Scienze Fisiologiche, Università "Carlo"

<sup>c</sup> Università Ca' Foscari di Venezia

Received 9 November 2006; received in revised form 29 January 2007

Available online 9 February 2007



<http://www.vettorpisani.net/>

# Antimicrobials: Endocrine Disruption in Rats

Crofton et al Triclosan

<http://www.ealing.gov.uk/>

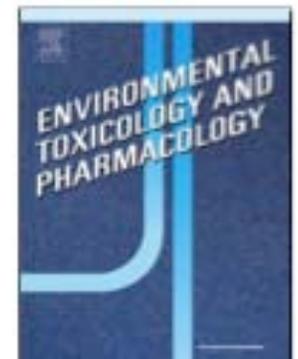
04/23/07



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

Kevin M. Crofton<sup>1</sup>, Katie B. Paul<sup>2</sup>, Michael J. DeVito<sup>3</sup> and Joan M. Hedge<sup>1</sup>

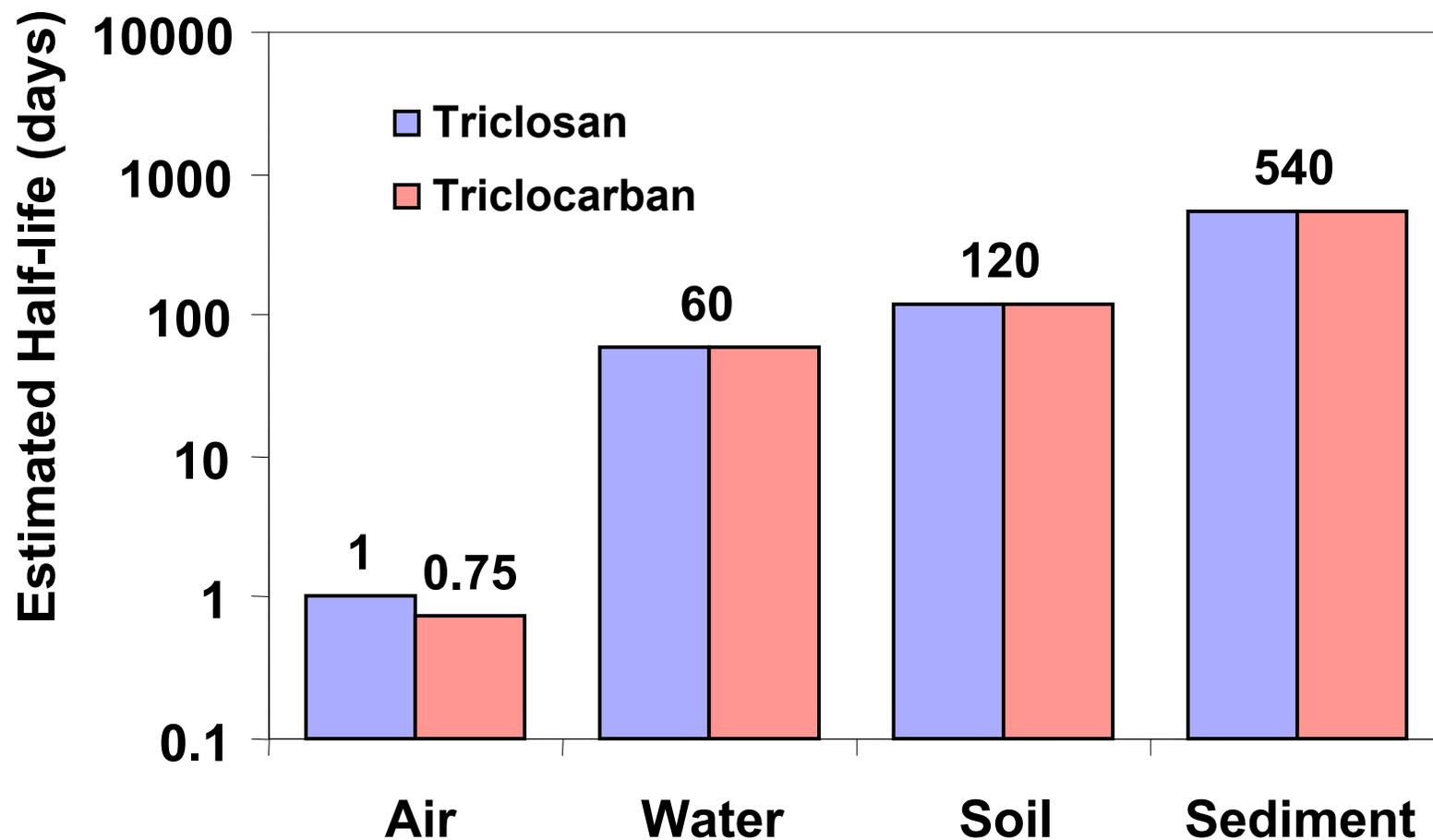
<sup>1</sup> Neurotoxicology Division and <sup>3</sup> Experimental Toxicology Division,  
National Health and Environmental Effects Research Laboratory,  
Office of Research and Development, U.S. EPA, Research Triangle Park, NC;  
<sup>2</sup> Curriculum in Toxicology, University of North Carolina, Chapel Hill, NC.



# What's Next? Do Persistent Antimicrobials Cause Endocrine Disruption in Humans?

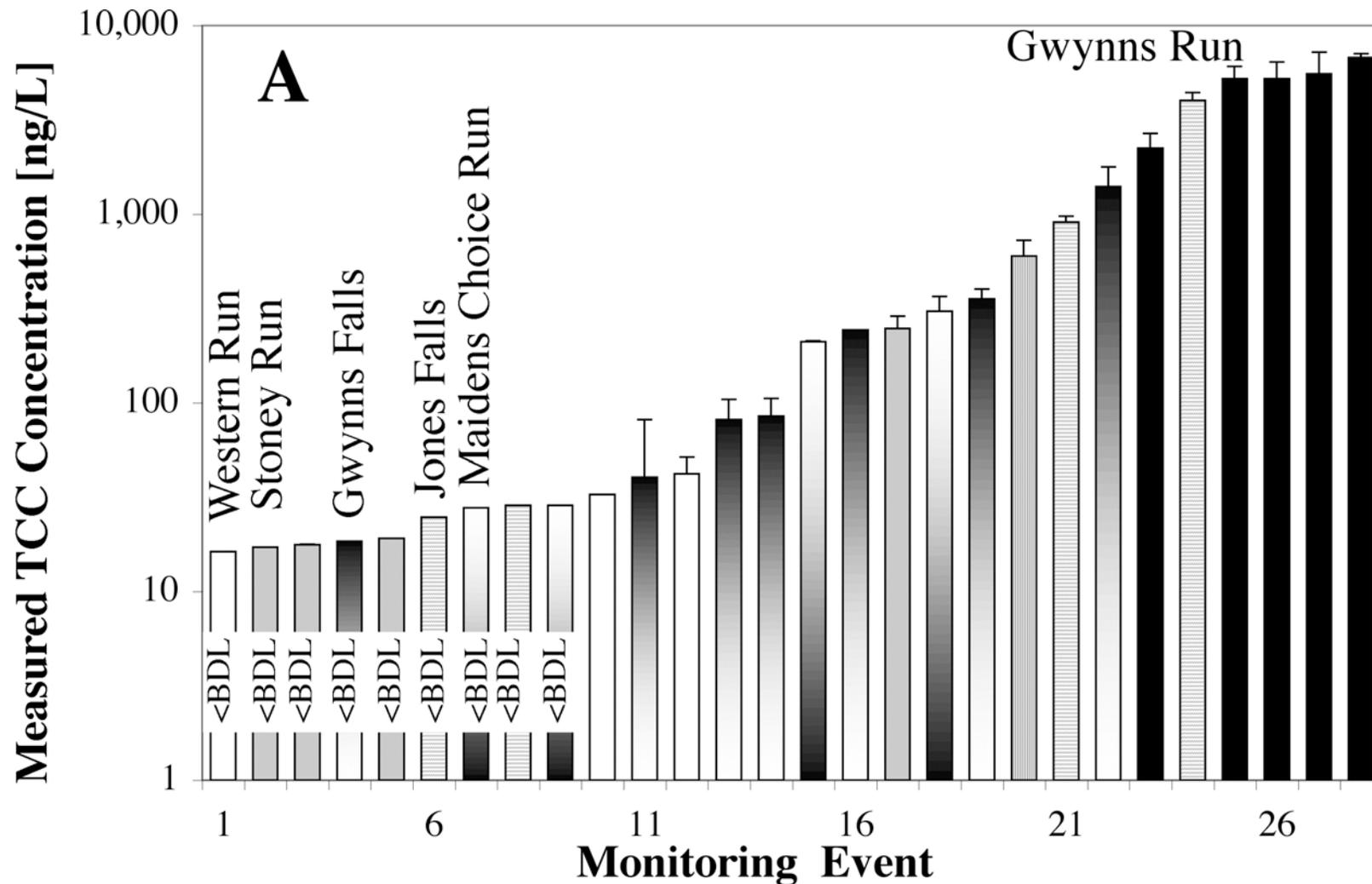


# Biocides Are Persistent Environmental Pollutants

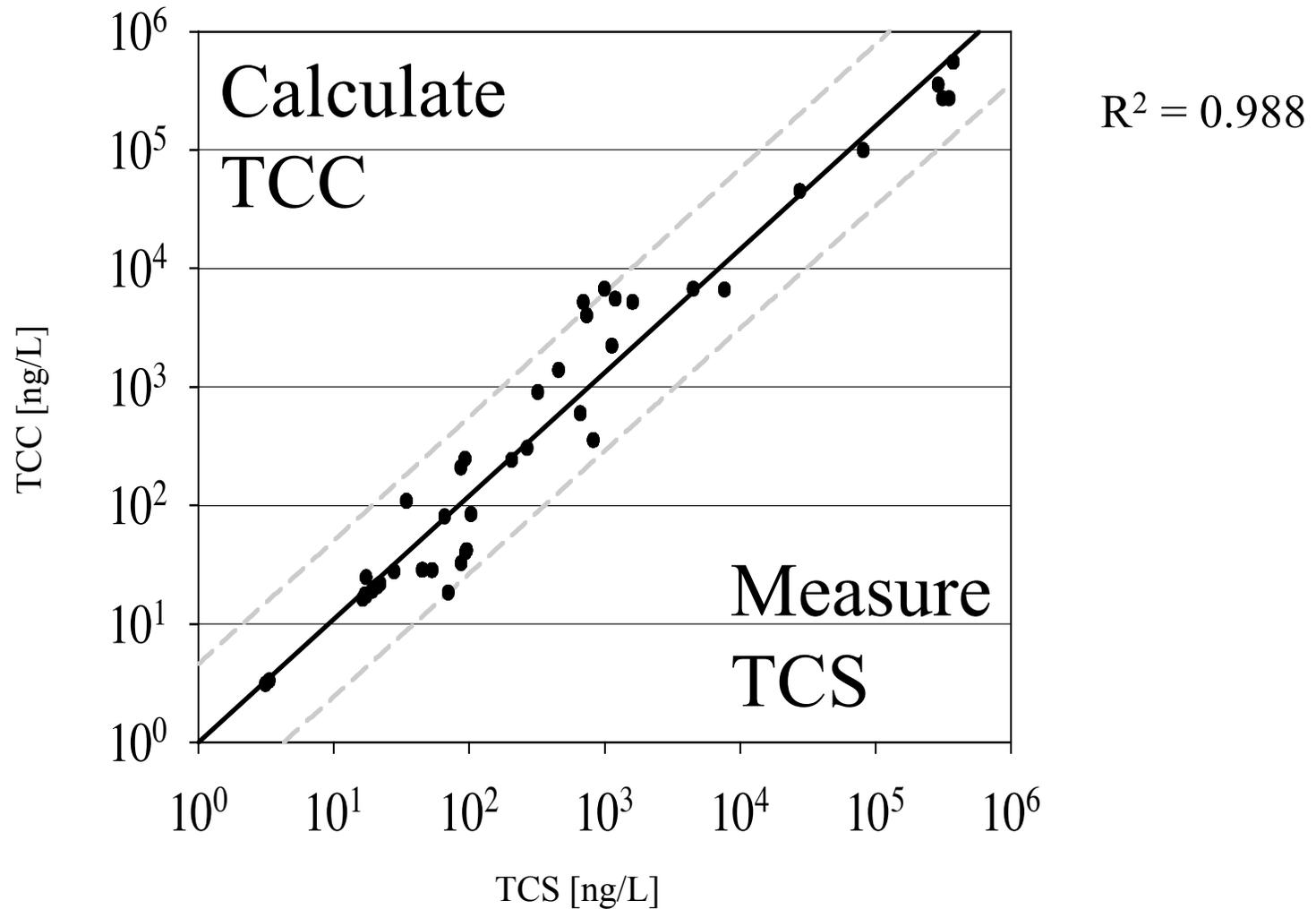


Estimated using quantitative structure activity relationship (QSAR) analysis

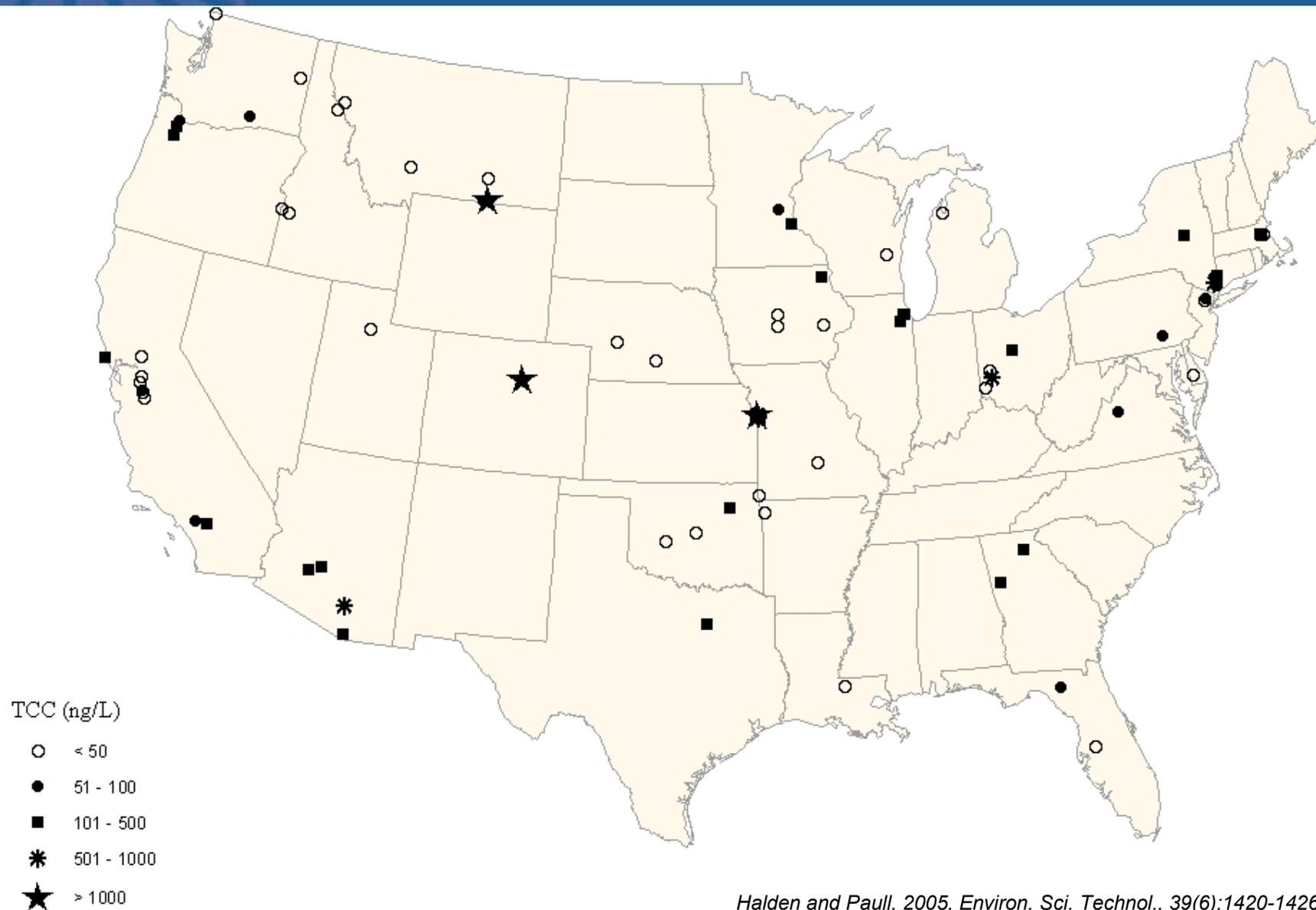
# Triclocarban Contamination Has Been Detected In All Baltimore Streams (But Not In All Locations)



# Co-Occurrence of TCC and TCS in MD Streams



# Predictions for 85 Streams Across the U.S.



# Predicted Nationwide Contamination Was Confirmed Experimentally in 2007

	<b>Model</b>	<b>Experimental</b>	
		Upstream	Downstream
Number of samples	85	18	18
Detection Frequency	60%	56%	100%
Mean [ng/L]	213	12 ± 15	84 ± 109

*Sapkota et al. (2007),  
Environmental Research  
103(1):21-29.*

# Antimicrobials Defy Wastewater Treatment

*Environ. Sci. Technol.* 2006, 40, 3634–3639

## Partitioning, Persistence, and Accumulation in Digested Sludge of the Topical Antiseptic Triclocarban during Wastewater Treatment

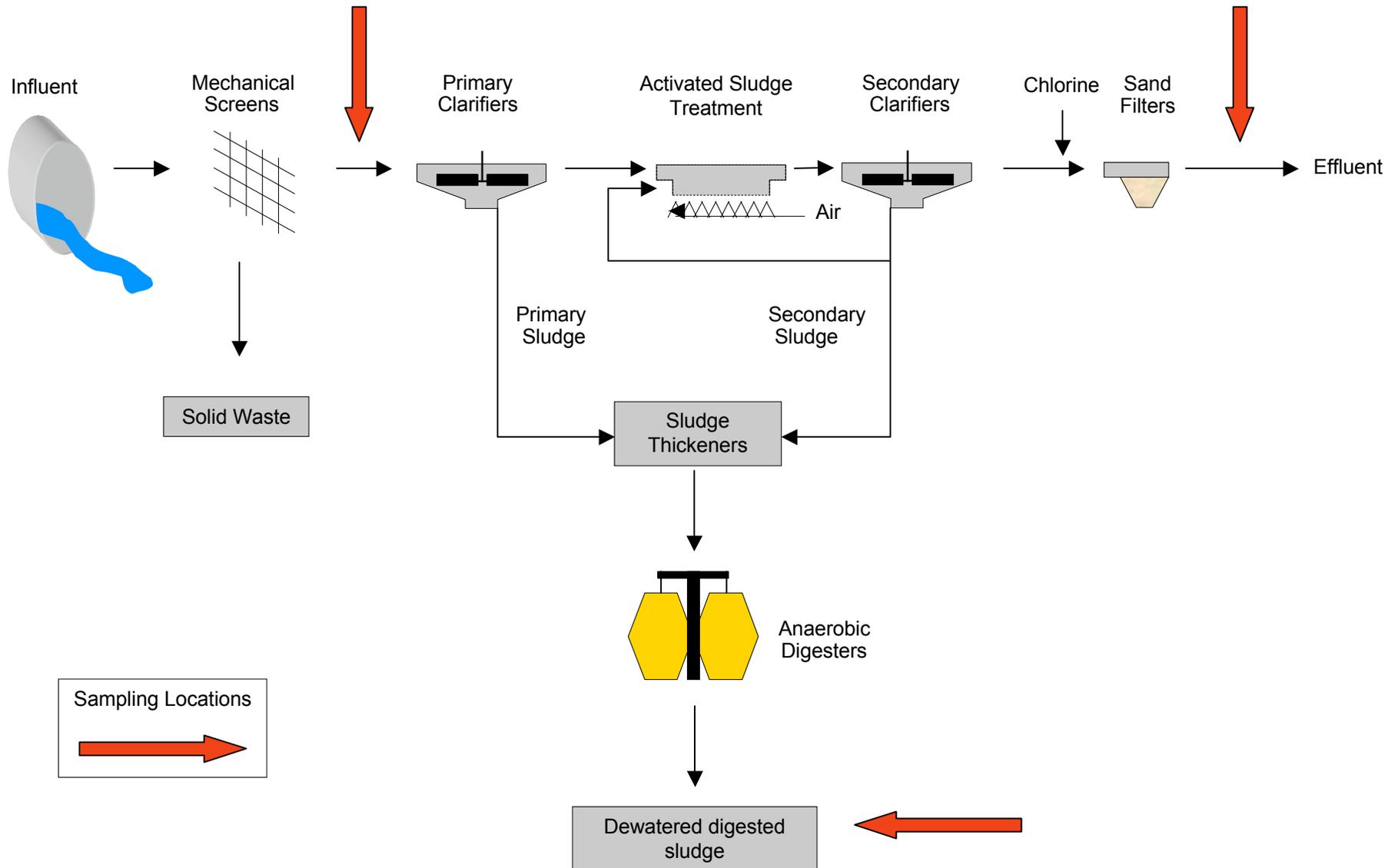
JOCHEN HEIDLER, AMIR SAPKOTA, AND ROLF U. HALDEN\*

*Department of Environmental Health Sciences, Bloomberg School of Public Health, Johns Hopkins University Center for Water and Health, Johns Hopkins University, 615 North Wolfe Street, Room E6618, Baltimore, Maryland 21205-2103*

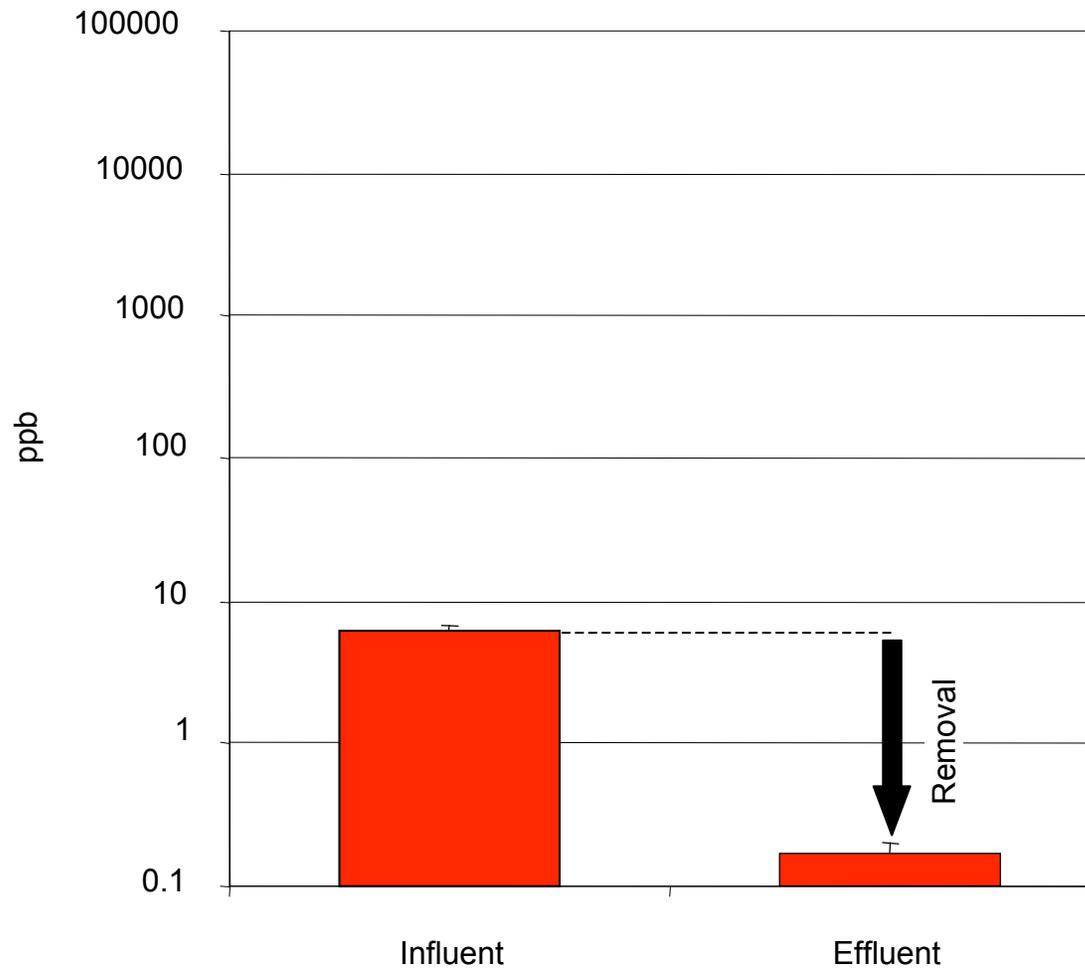
attention has been focused on PPCPs passing through conventional wastewater treatment plants (WWTPs) and becoming detectable in effluent-receiving streams (3), few studies have explored the partitioning of compounds into municipal wastewater residuals and their subsequent fate during sludge treatment (1, 4, 5). This lack of information is due in part to the difficulty of accurately detecting and quantifying PPCPs in the challenging analytical matrix of municipal sludge. Previously, our laboratory employed isotope dilution gradient liquid chromatography with electrospray ionization mass spectrometry (6) to perform a preliminary analysis of the behavior of PPCPs in a large activated sludge WWTP (5). Following development of a more selective method using triple quadrupole tandem mass spectrometry (7), this novel tool was applied to conduct a mass balance for a specific PPCP whose environmental fate has long been neglected (4).

- Activated sludge WWTP
- 600 ML/D (180 MGD)
- Population served: 1.3 M

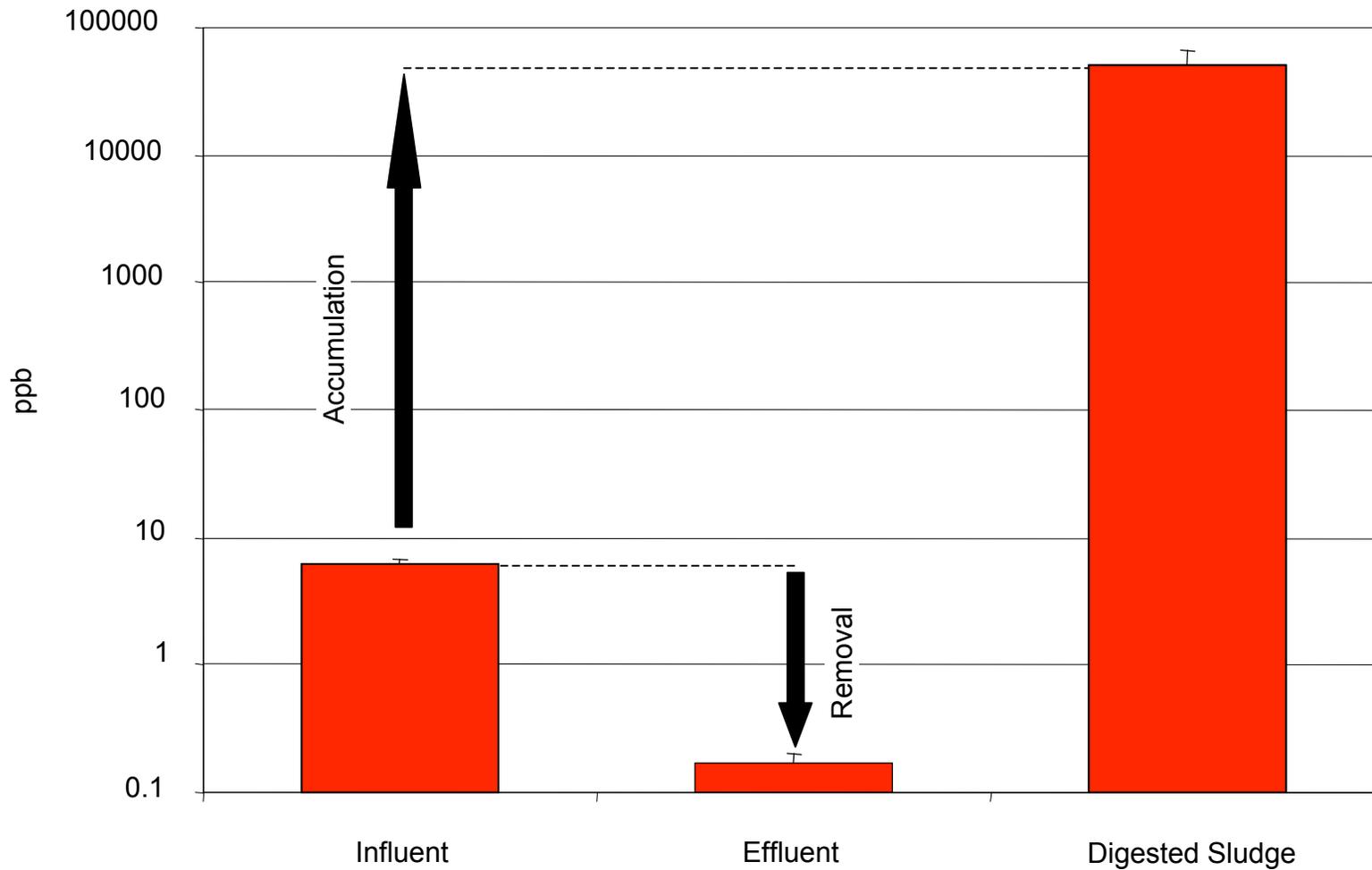
# Process Diagram of Activated Sludge Wastewater Treatment Plant



# Triclocarban Is Removed From Wastewater...



# ...Only to Accumulate in Sludge



# Mass Balance Calculation



$$M_{trans} = (Q_{inf} \times C_{inf}) - (Q_{eff} \times C_{eff}) - (TS_{dig} \times Q_{dig} \times C_{dig}) - M_{vol}$$

**M = Mass loading (kg/d)**

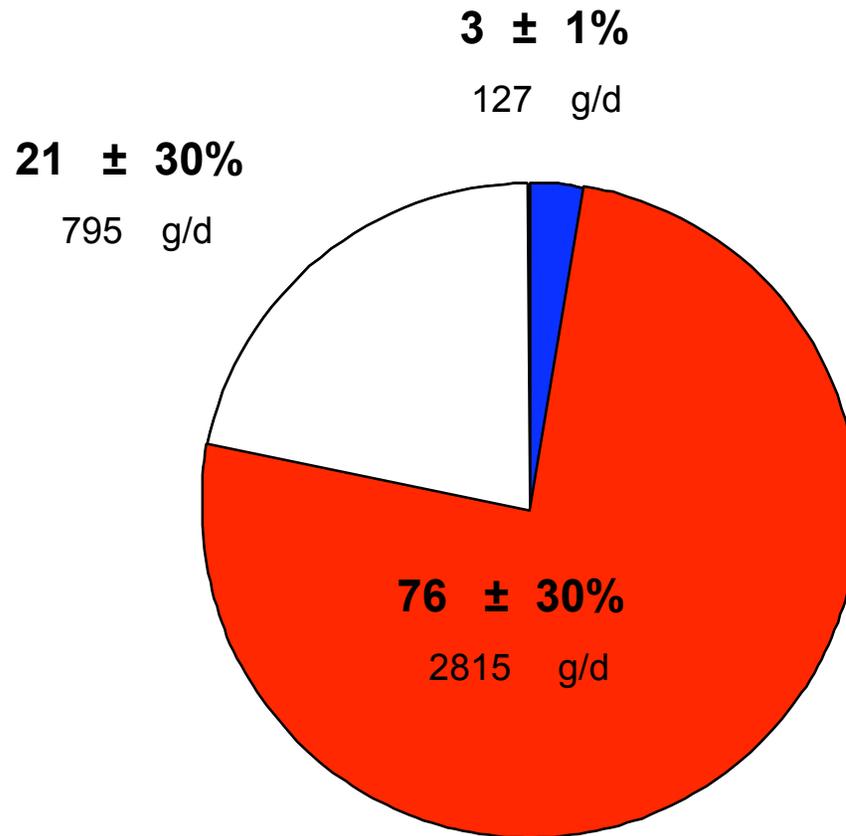
**Q = Flow rate (L/d)**

**C = Concentration (g/L)**

**TS = Total solids (%)**

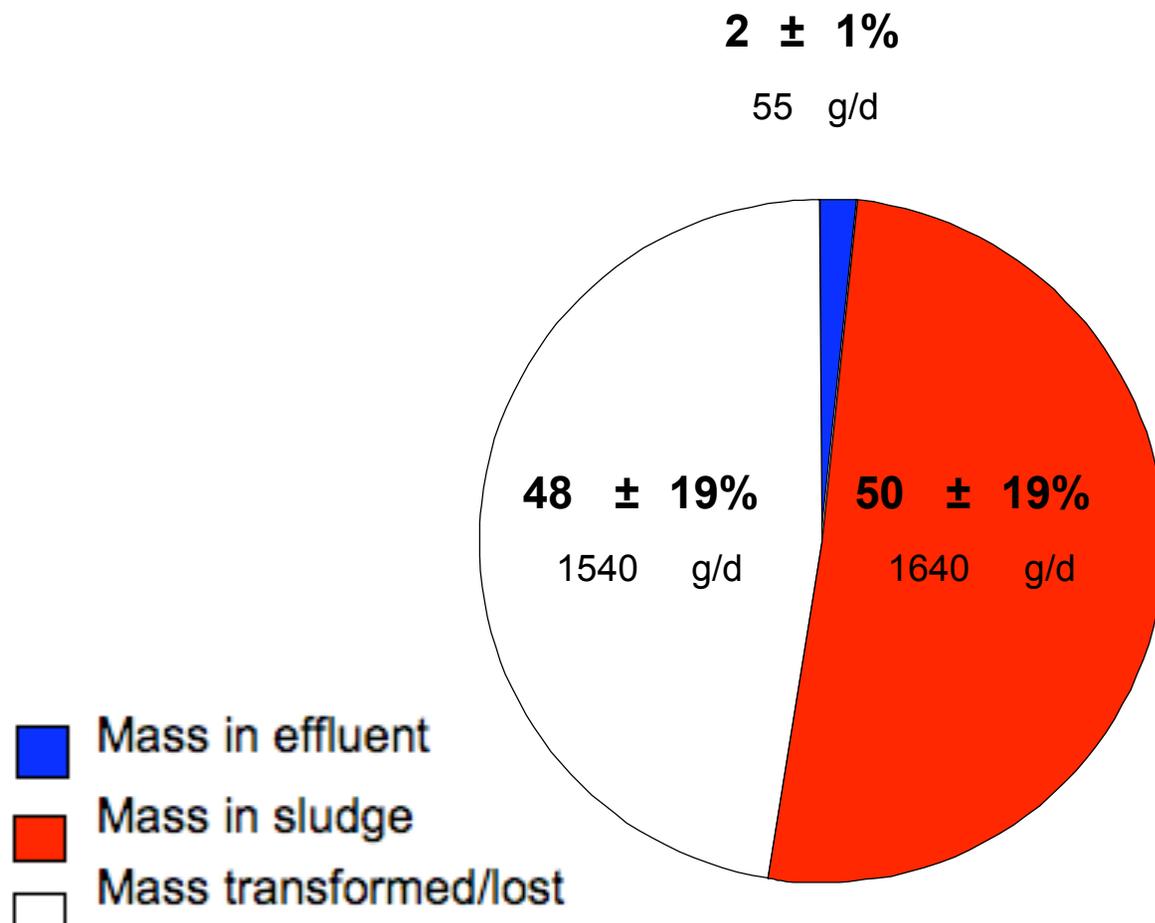
**$M_{vol}$  = negligible**

# TCC Mass Balance for a Mid-Atlantic Plant



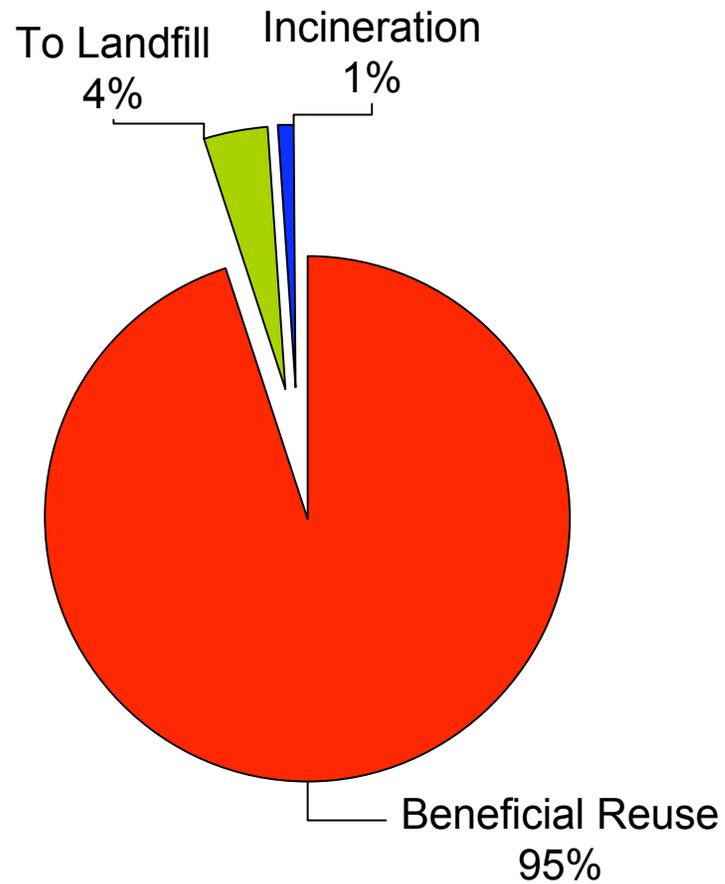
-  Mass in effluent
-  Mass in sludge
-  Mass transformed/lost

# Triclosan Mass Balance for a Mid-Atlantic Plant



Heidler & Halden, *Chemosphere* (2007)  
66(2):362-369

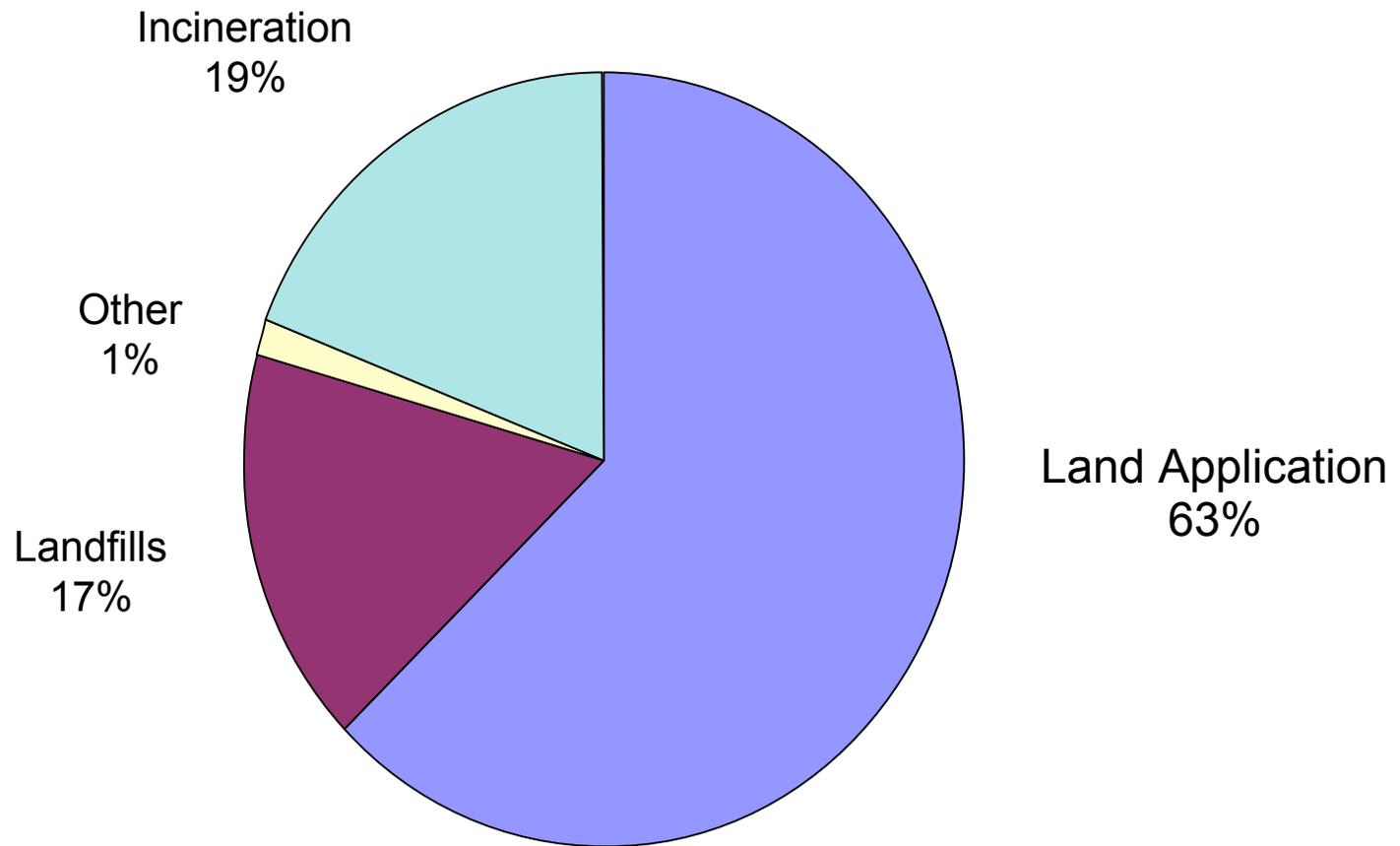
# Fate of Sludge Produced at the WWT Plant



Heidler et al. (2006) *Environ. Sci. Technol.* 40(11) 3634-3639.

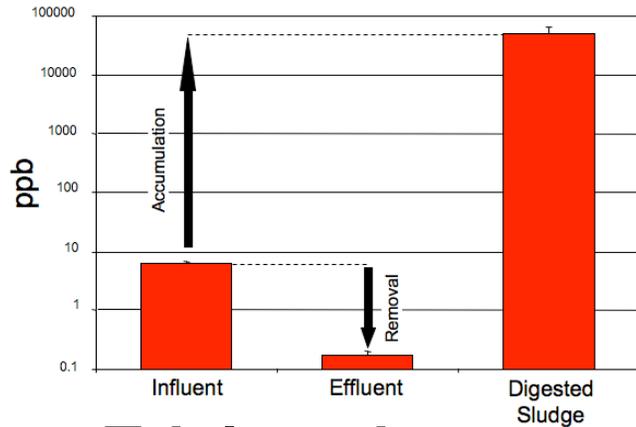
# Estimated Mass & Use of Biosolids in U.S.

12.5 Billion dry lb/yr (125,000 railroad cars) of sludge



*Biosolids Applied to Land, National Research Council of the National Academies, 2002*

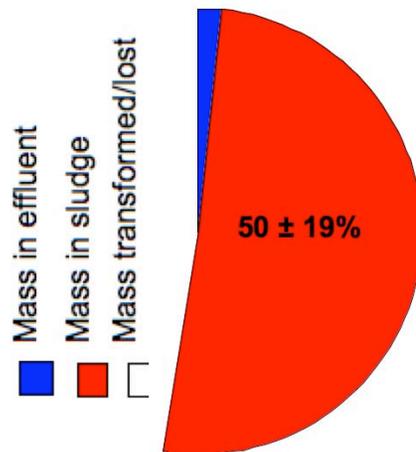
# Biocide Inputs to Agricultural Soils



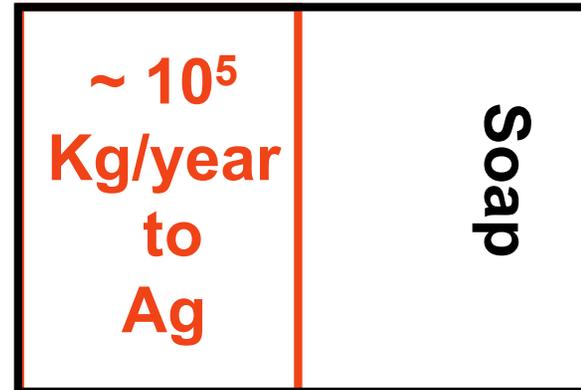
**Triclocarban**



*ES&T 40(11) 3634-39, (2006)*

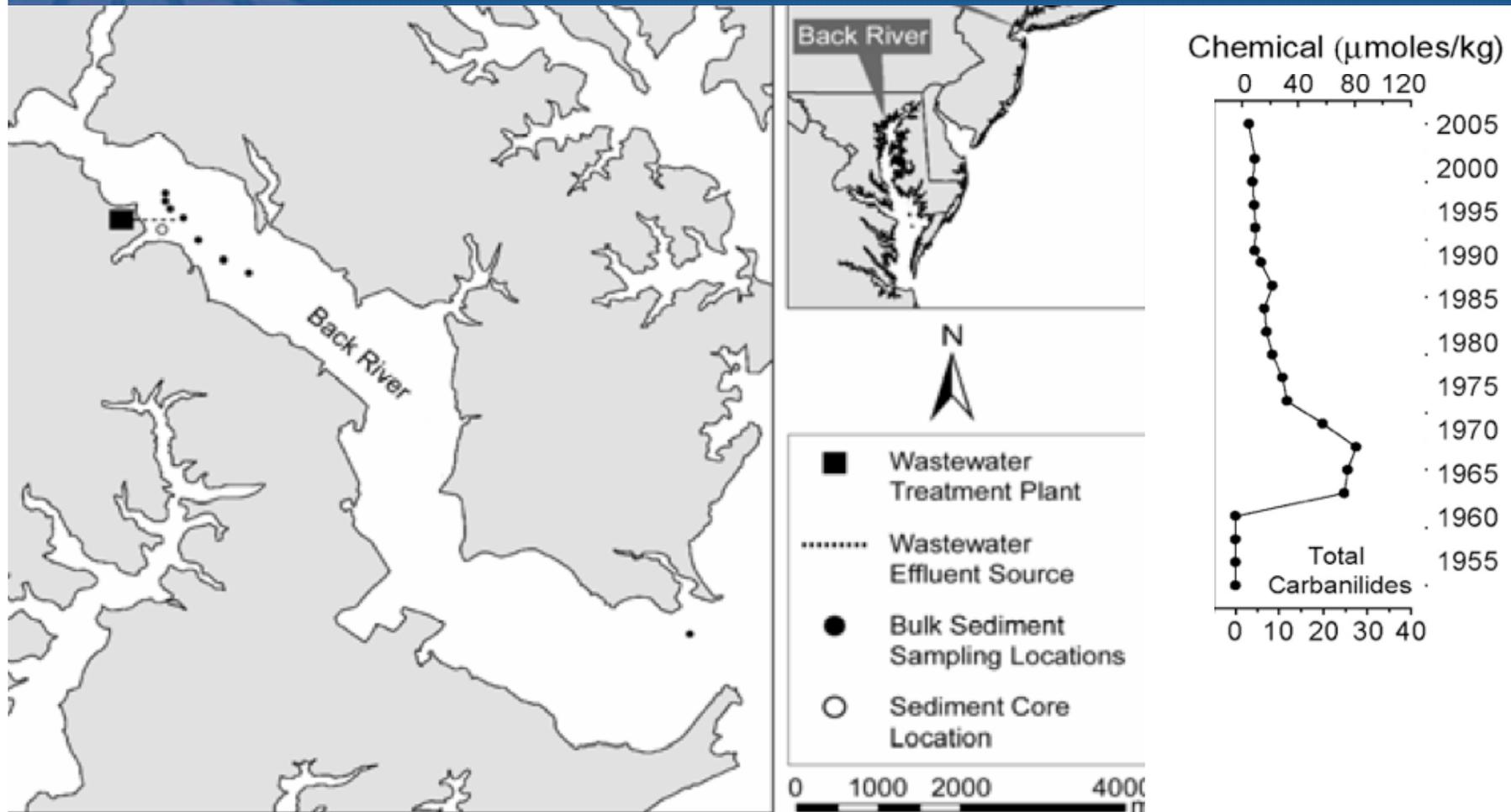


**Triclosan**



*Heidler & Halden, Chemosphere 2007*

# Antimicrobials in Chesapeake Sediments



# A Look into the Future: More of the Same?

## **Triclosan & Triclocarban: continuing down the path of polyhalogenated organic mistakes:**

- 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
- accumulate in algae
- endocrine disruptors
- promote cross-resistance to clinically important antibiotics
- contain dioxin & carcinogenic impurities
- degrade to form additional carcinogens
- environmentally persistent
- potentially interfere with the microbial loop (i.e., the environmental cycling of elements by microorganisms)
- 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

# Lessons (To Be) Learned

- **Polyhalogenated organics are incompatible with nature's principle of cycling of elements**
  - should be avoided wherever possible
- **A need for beginning to see “waste” as a resource**
  - e.g., “wastewater” really is raw drinking water; it should be protected from unnecessary chemical contamination (polyhalogenated organics, metals, etc.)
- **Control chemical inputs into the environment more tightly**
  - evidence of failure to learn from past mistakes
- **Pollution prevention is the fastest, most economical and most effective way of improving environmental and human health**
  - applies to pesticides, organohalides, pharmaceuticals, personal care products, etc.
- **Adopting these lessons will support the microbial loop, assist in wildlife conservation & protect human health**

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- Guy Hollyday
- John Martin and Nick Frankos

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