



# Emerging Contaminants in the Environment

**NACWA 2009 Summer Conference**

Dana Kolpin

Toxic Substances Hydrology Program

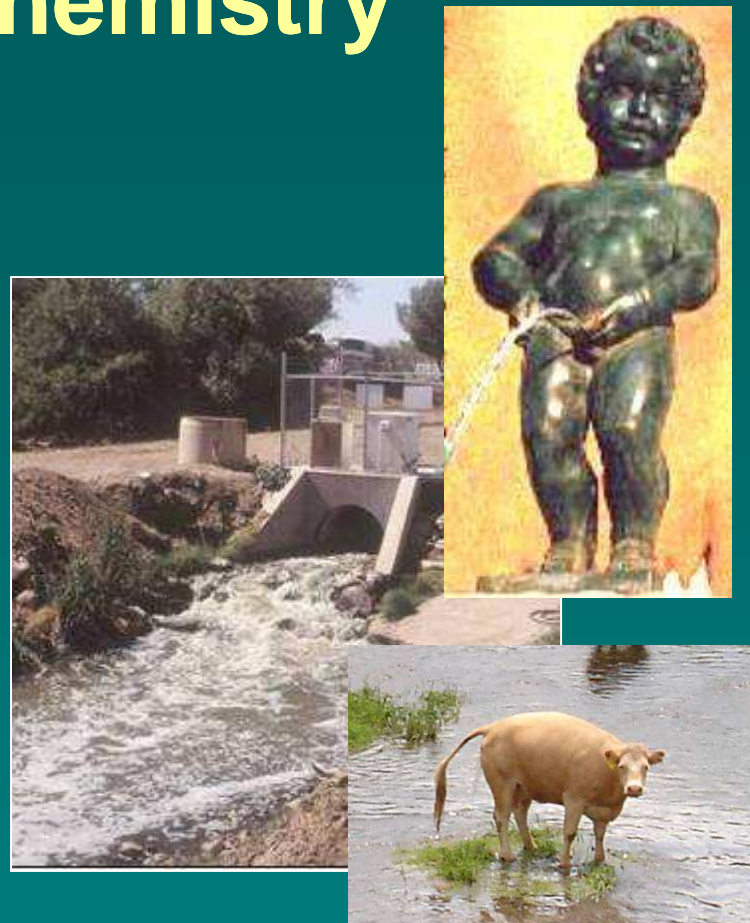
March 15, 2009

U.S. Department of the Interior  
U.S. Geological Survey

# Better Living Through Chemistry



# From our homes, farms and workplaces



# To our water resources



x1000s of chemicals are in use daily

## Mornings Have Never Been So Invigorating!



“Tired of waking up and having to wait for your morning java to brew? Are you one of those groggy early morning types that just needs that extra kick?”

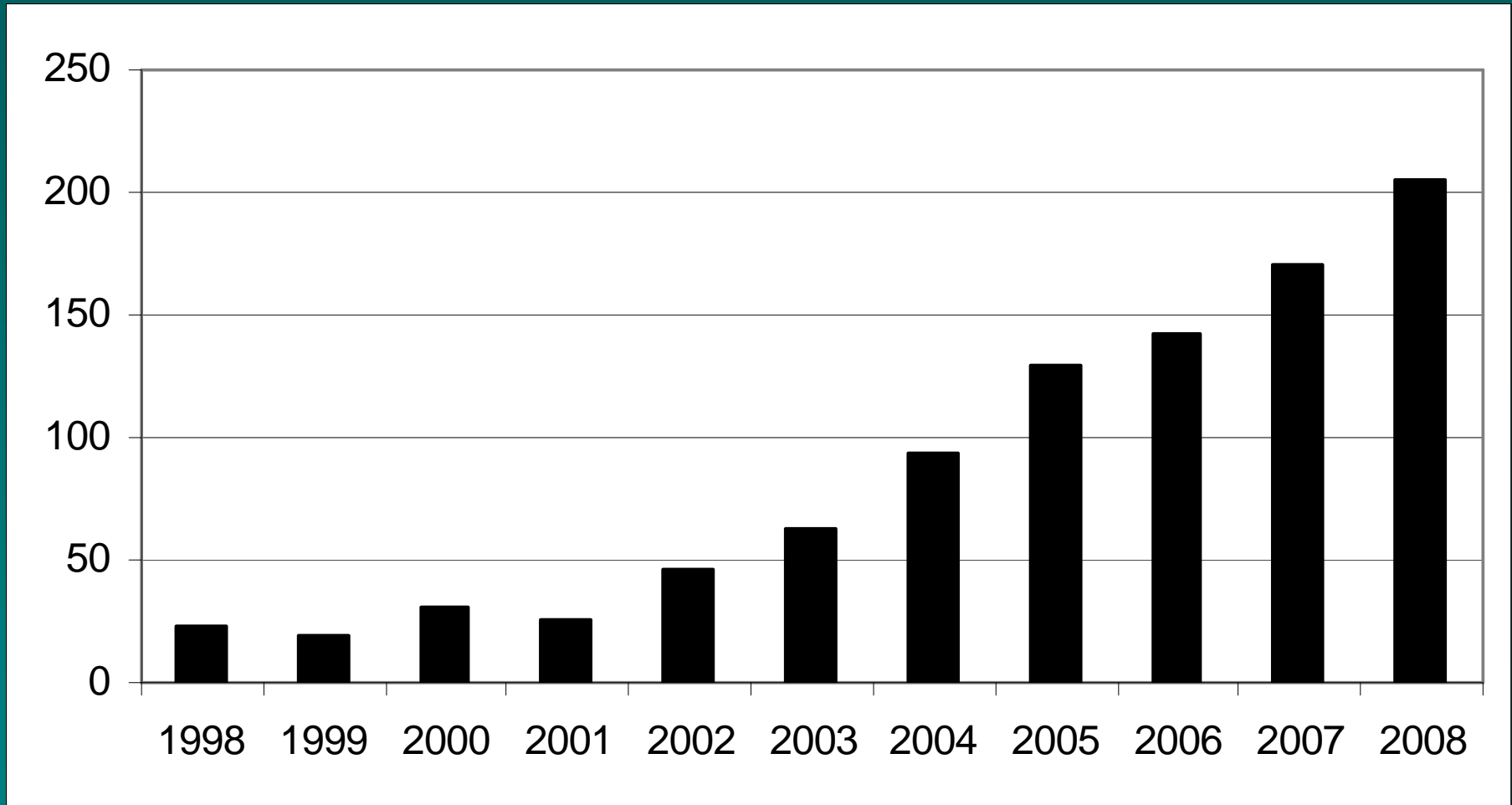
12 servings/showers per 4 ounce bar (200 mg of caffeine per serving).  
The caffeine is absorbed through the skin.



# Measurement Capabilities

- **Illicite drugs** (Bijlsma et al., 2009)
- **glucocorticoids** (*Chang et al., 2007*)
- **antidepressants** (*Vanderford et al., 2006; Schultz et al., 2008*)
- **fibrates** (*Loraine et al., 2006 & Soliman et al., 2007*)
- **barbiturates** (*Peschke et al., 2006*)
- **cytostatics** (*Buerge et al., 2006*)
- **psychoactive drugs** (*Kreuzinger et al., 2004; Hummel et al., 2006*)
- **muscle relaxants** (*Soliman et al., 2004*)
- **beta-blockers** (*Huggett et al., 2003*)
- **PCPs / wastewater chemicals** (*Zaugg et al., 2002*)
- **antiphlogistics** (*Ternes et al., 2001*)
- **antibiotics** (*Meyer et al., 2000; Lindsey et al., 2001*)

# EC Research has picked up speed since 1998



Glassmeyer et al., 2008

# Fundamental Research Questions

- *Are ECs entering our environment?*
- *What are the sources (signatures)?*
- *What happens to ECs in the environment?*
- *Do ECs have adverse ecological health effects?*
- *Do unintended exposures to ECs pose a human health risk?*
- *How can we minimize their entry to the environment or remove them?*



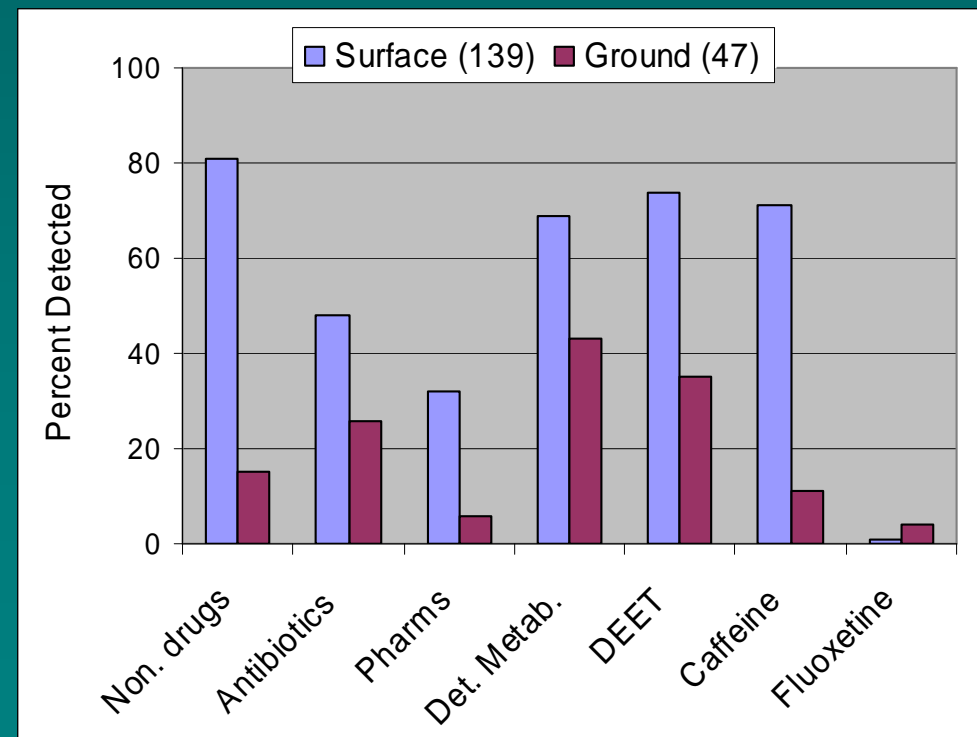
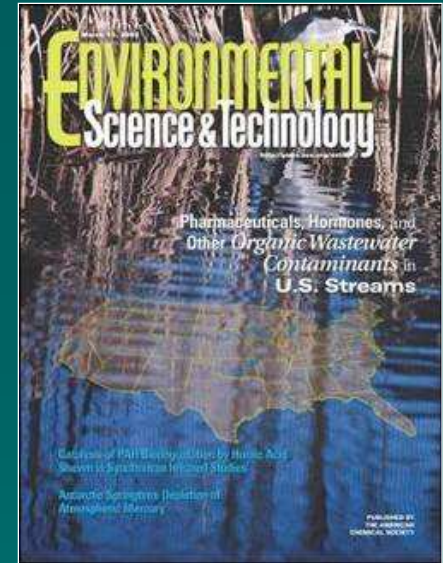
# Source-to-Receptor Research

<http://toxics.usgs.gov/regional/emc/>



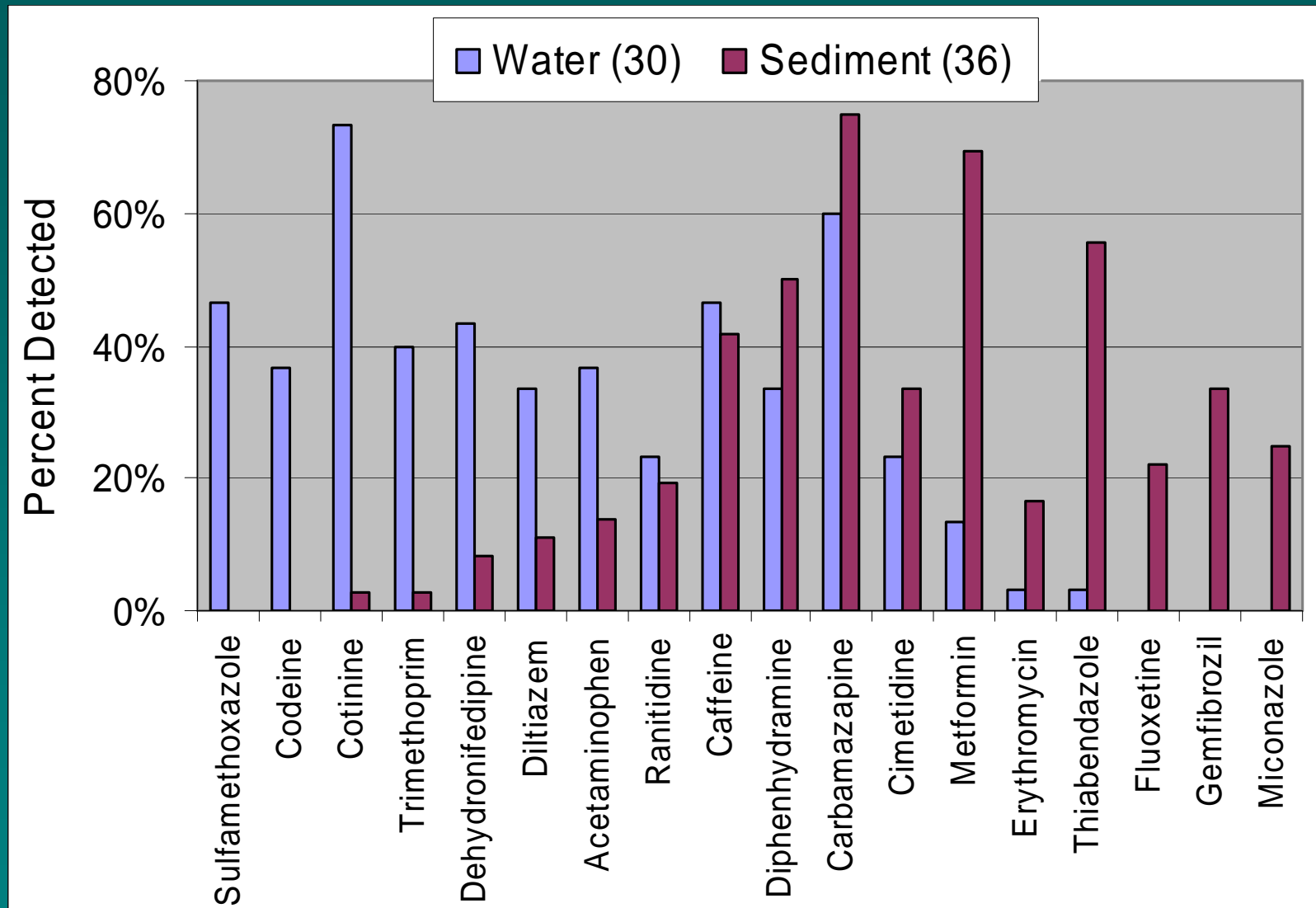
# Are ECs entering our environment?

- Present in ground water and streams at sub-ppb conc.'s.
- Present as complex mixtures.
- Entering via human & animal waste pathways.





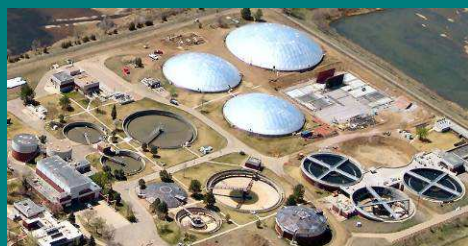
# ECs -- don't look just in the water!



# What are the potential sources?

## Human

- Wastewater treatment plants
- Land application
- Combined sewer overflows
- Onsite septic systems
- Industrial/commercial discharge
- Landfills
- Water reuse

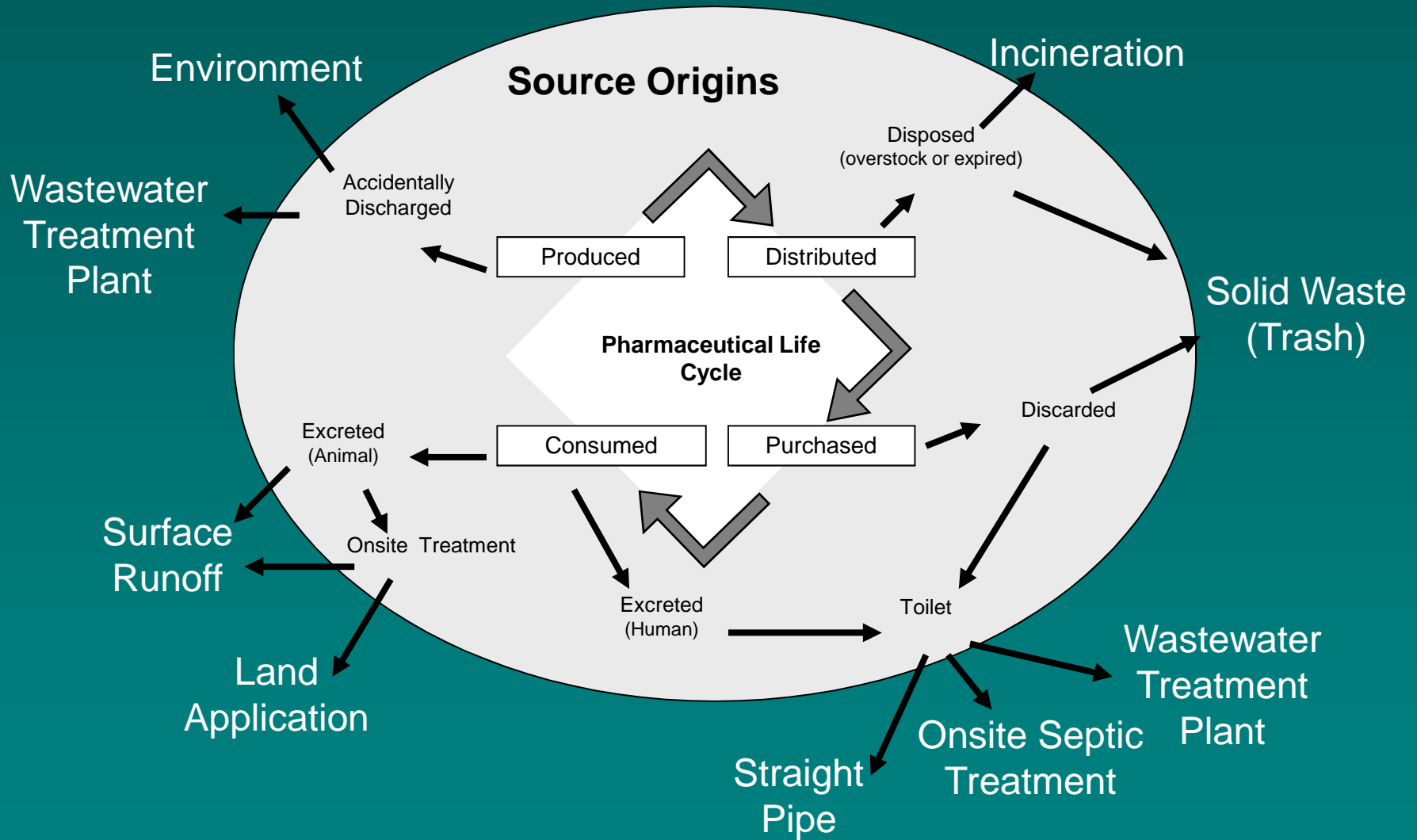


## Animal

- Waste lagoons, etc.
- Land application
- Processing plants
- Aquaculture



# Source Pathways



# Source Characterization - urban



L

TCS 1.6 ug/L

SX 0.59

TM 0.35



S

32,900 ug/kg

160

22



L

82 ug/L

2

0.23

S

19,000 ug/kg

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Glassmeyer et al, 2005; Kinney et al.,  
2006; Conn et al., 2006

# ECs in Biosolids Destined for Land App

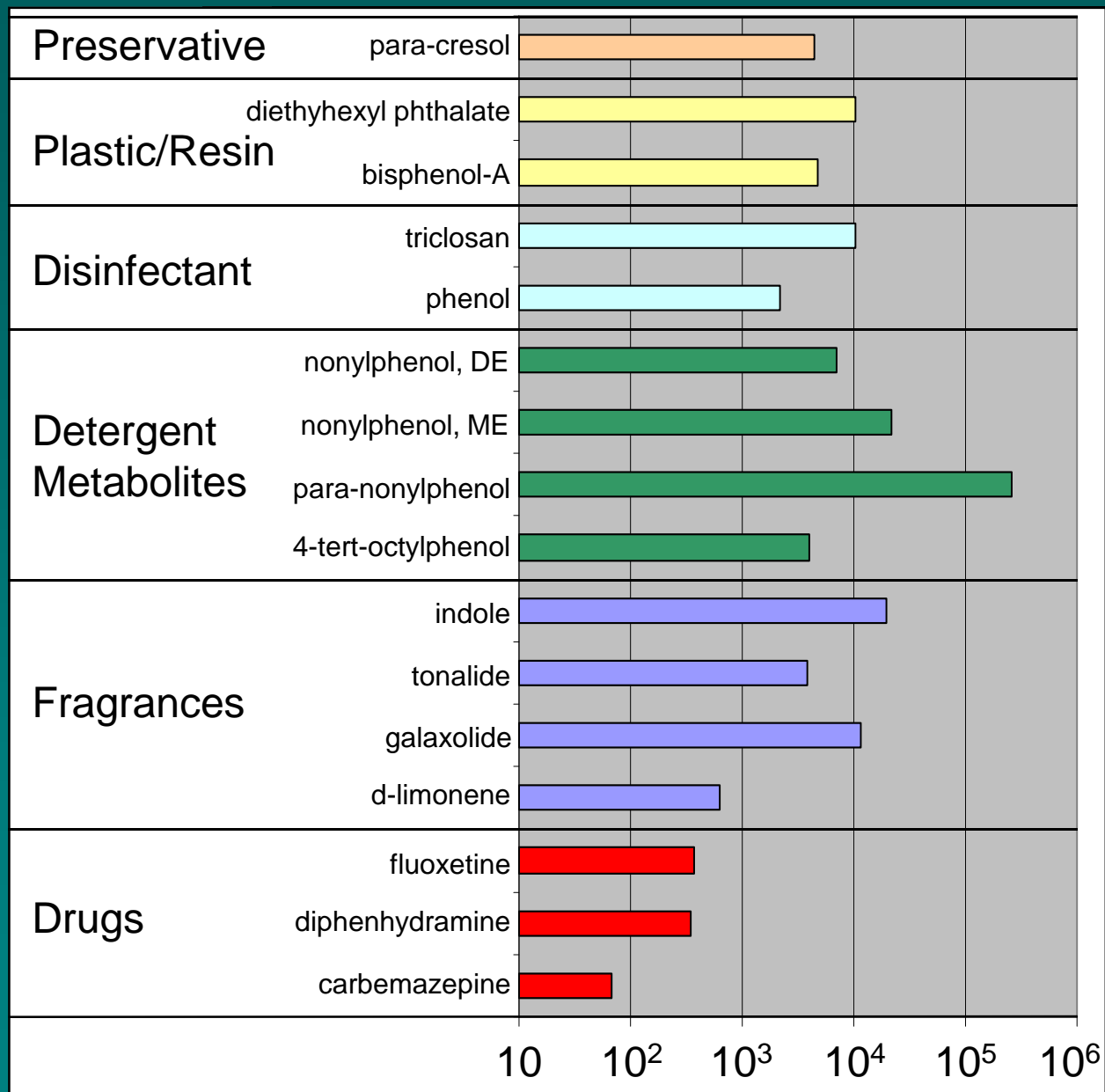
## 9 Locations



Median, Carbon-Normalized Concentrations, in  $\mu\text{g/kg}$ .

10-40% Carbon.

*Kinney et al., 2006*





# Pharm. Manufacturing Facilities

## WWTP near Hyderabad India

- Receives effluent from 90 bulk drug manufacturers.
- Range: 2 samples from consecutive days.

Active Ingredient	Drug Type	Range (µg/L)
Ciprofloxacin	antibiotic	28,000-31,000
Losartan	angiotensin II receptor antagonist	2,400-2,500
Cetirizine	H <sub>1</sub> -receptor antagonist	1,300-1,400
Metoprolol	B <sub>1</sub> -adrenoreceptor antagonist	800-950
Enrofloxacin	Antibiotic	780-900
Citalopram	SSRI	770-840
Norfloxacin	antibiotic	390-420
Lomefloxacin	antibiotic	150-300
Enoxacin	antibiotic	150-300
Ofloxacin	antibiotic	150-160

*Larsson et al., 2007*

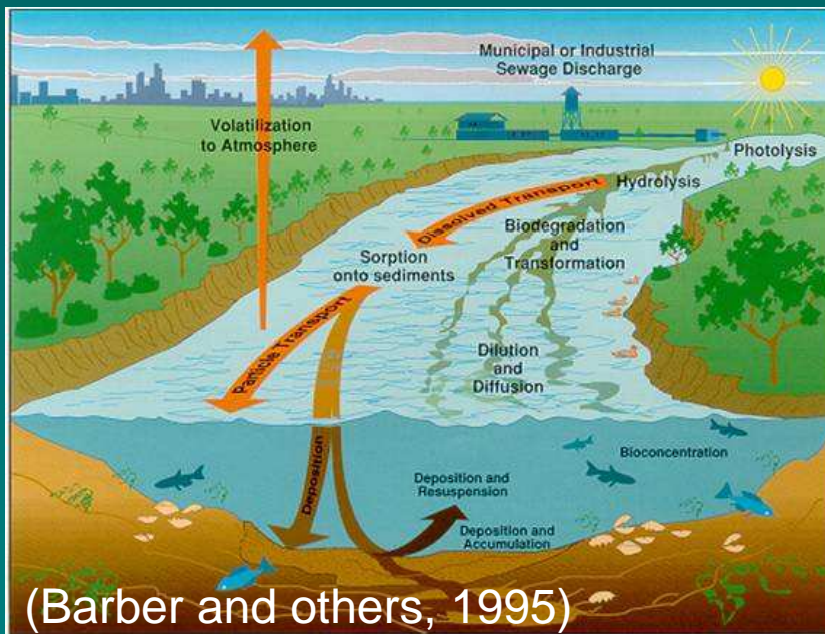
# Transport and Fate

Quantify transformation processes (dilution, sorption, biodegradation, abiotic transformation).



## Research being Conducted

- **Fate through WWTPs**  
(WERF, Metcalf & Eddy, and U of AZ)
- **Fate through DWTPs**  
(USGS, USEPA)
- **Surface transport**  
2 research basins (Boulder Creek, CO  
Fourmile Creek, IA)
- **Subsurface transport**  
Cape Cod Research Site



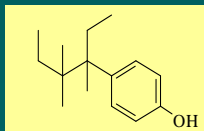
*In order to minimize ecologic effects, it is essential to understand how a contaminant moves and is altered in the environment.*



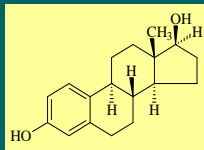
# Subsurface tracer experiments – Cape Cod Research Site

## Target ECs

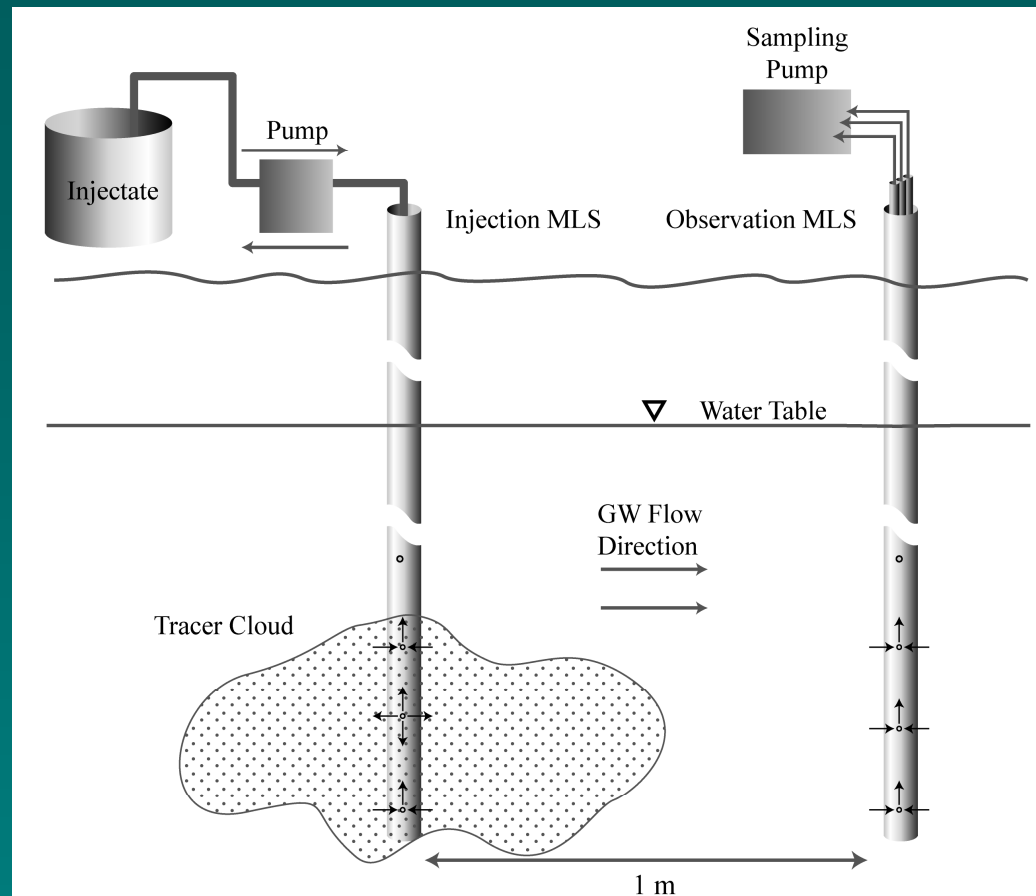
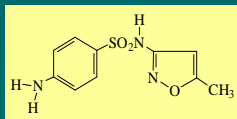
NP



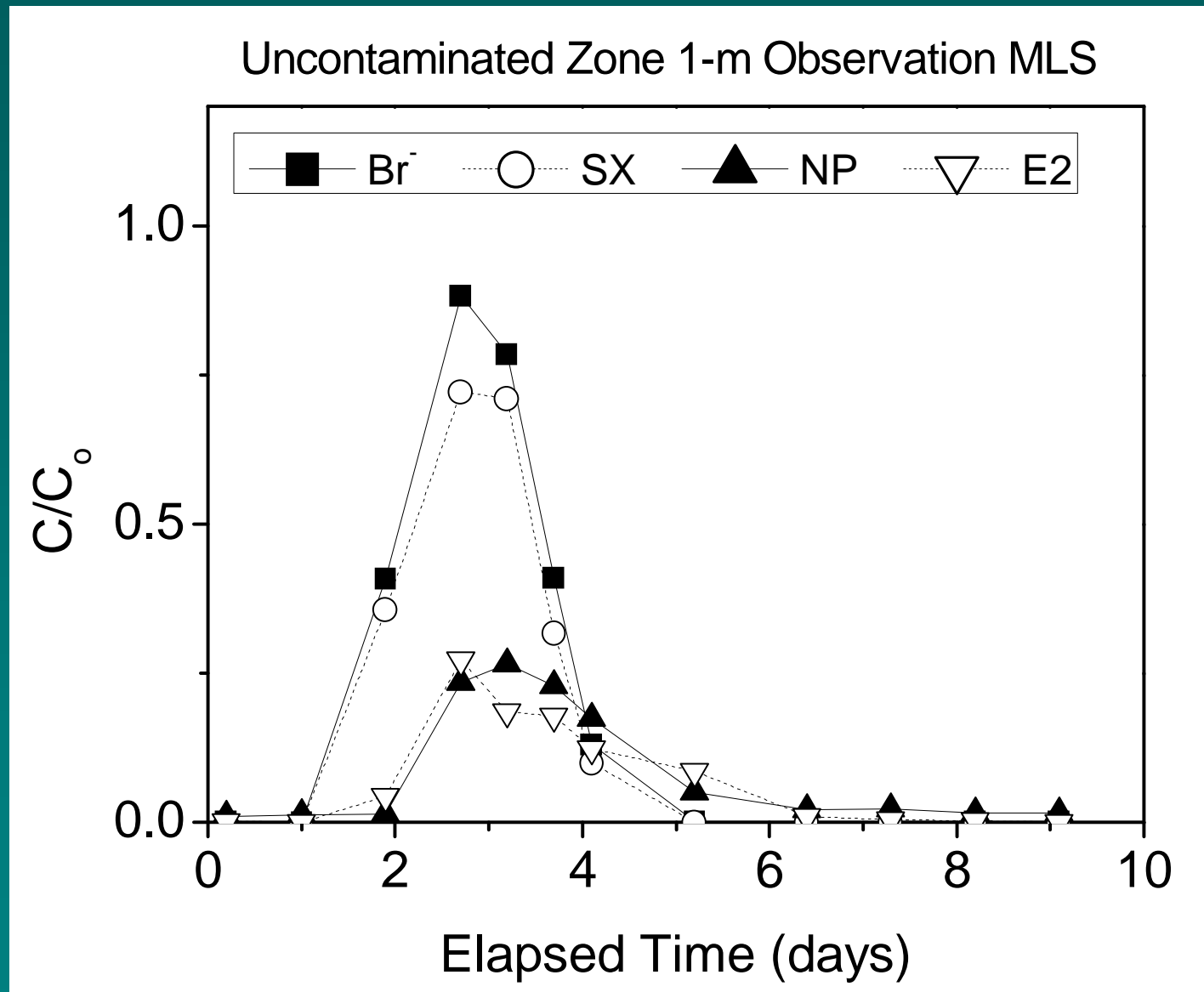
E2



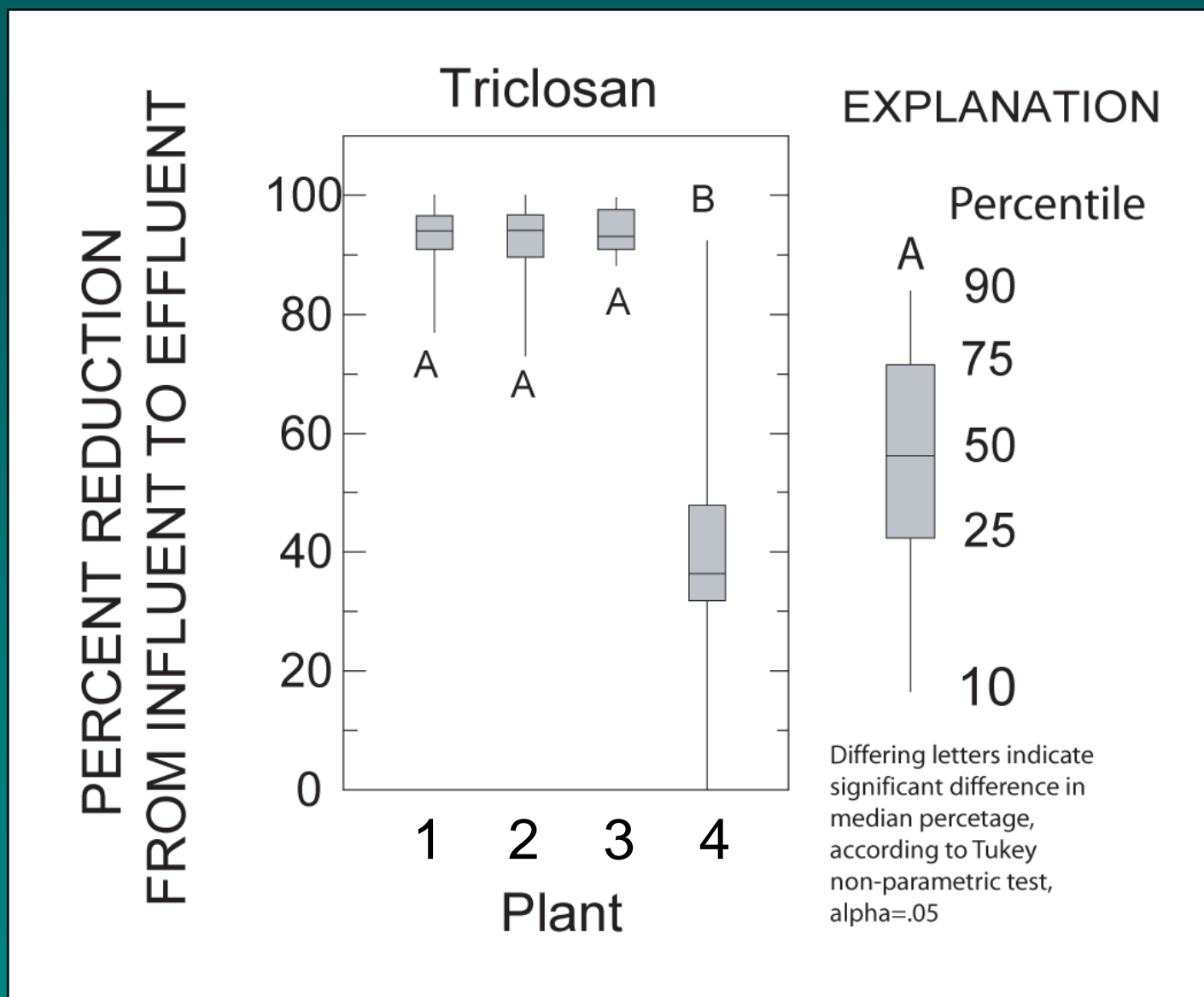
SX



# Conservative subsurface transport of sulfamethoxazole

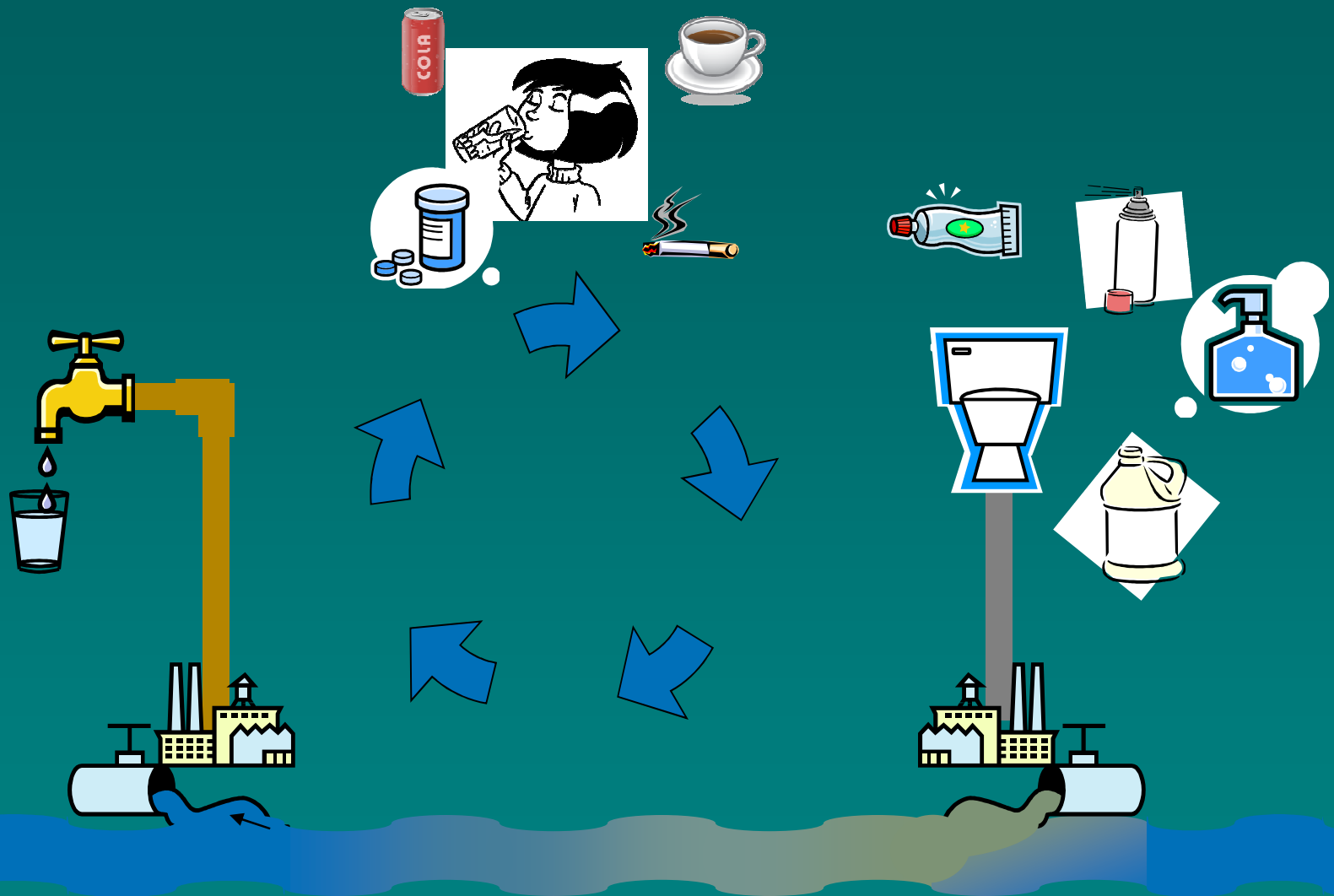


# WWTPs Vary In Ability To Reduce Antimicrobials





# Potential Pathway to DW





Mike Keefe THE DENVER POST 03/13/08



Mike Keefe, The Denver Post



# PUR

WATER FILTRATION SYSTEM



3-STAGE FILTER FOR CRISP, REFRESHING TASTE



PUR<sup>®</sup>  
Faucet Mount  
Filters

can  
remove  
over **99%** of  
Pharmaceuticals\*

\*Based on manufacturer  
testing for reduction in  
levels of 12 pharmaceuticals.  
Pharmaceuticals may not be  
in all users' water.  
Pharmaceutical Reduction  
Not Certified by NSF  
International

Model / Modelo FM-3700

1 SYSTEM, 1 FILTER/  
1 SISTEMA, 1 FILTRO



## 3 Stage FILTER

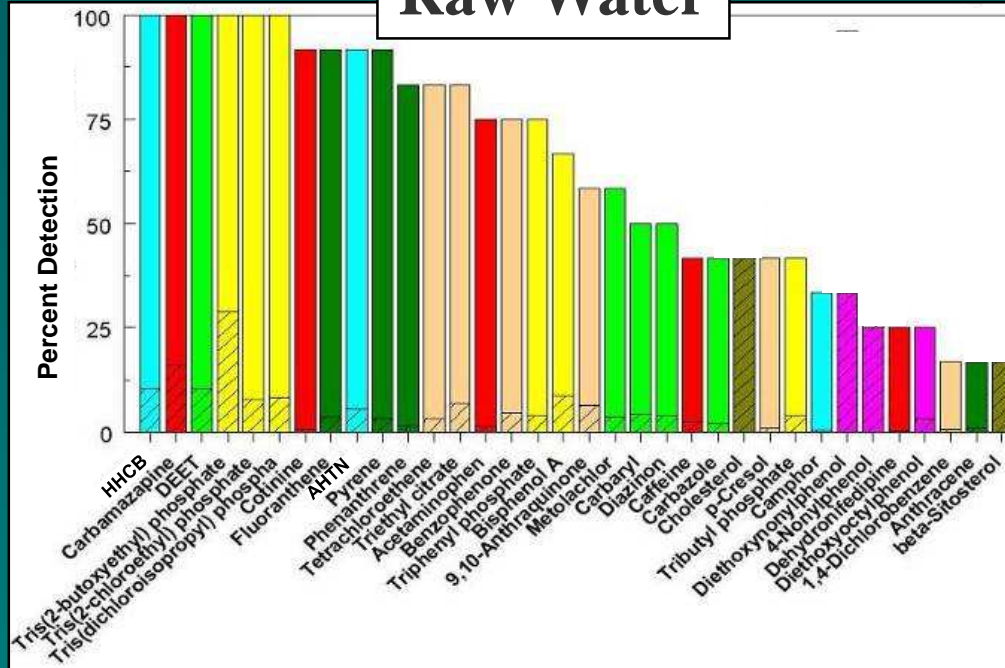
Our **ULTIMATE** in FILTRATION  
and a CRISP, REFRESHING TASTE

removes **99.9%**  
MICROBIAL CYSTS,  
CRYPTOSPORIDIUM and GIARDIA

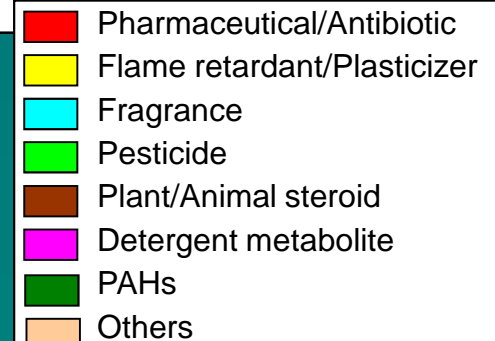
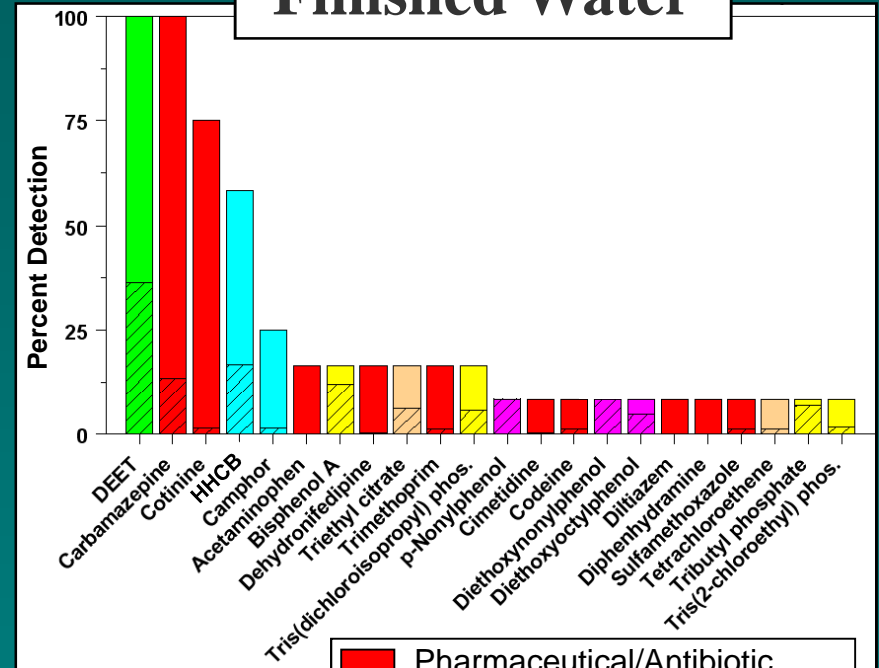
PARA INFORMACIÓN EN ESPAÑOL, VEA LOS PANELES LATERALES Y EL PANEL POSTERIOR

# Reduction via Treatment

**Raw Water**



**Finished Water**



*Stackelberg et al., 2004 & 2007*

# In-stream Study of ECs

Fourmile Creek (IA)



Boulder Creek (CO)



- Effluent dominated systems (WWTP discharge)
- Background data denote multiple ECs present
- Relatively small basin sizes
- Basic understanding of the flow system
- Controls present above WWTPs
- WWTPs undergoing major changes







# Fourmile Comparison



<i><b>ANTIDEPRESSANT</b></i>	<i><b>WW EFF ng/L</b></i>	<i><b>Brain, 0 km ng/g</b></i>	<i><b>Brain, 8.4 km ng/g</b></i>
Fluoxetine	4.4	0.13	0.15
Norfluoxetine	1.3	0.5	0.3
Sertraline	2.8	0.6	0.33
Norsertraline	2.3	3	1.1
Paroxetine	0.7	0.006	0.01
Citalopram	27	0.009	0.01
Bupropion	42	0.03	0.04
Venlafaxine	210	ND	ND

# Documented uptake of ECs into plant and animals

- Oxytetracycline in alfalfa (Kong et al., 2007).
- Trimethoprim in carrots and lettuce (Boxall et al., 2006).
- Sulfamethazine in corn, lettuce, potatoes (Dolliver, et al., 2007)
- Trimethoprim and triclosan in earthworms (Kinney et al., 2008).
- Triclosan and methyl-triclosan in carp (Leiker et al., 2008)
- Antidepressants (Brooks et al., 2005) and PPCPs (Rameriz et al., 2009) in fish
- Triclosan in dolphin (Fair et al., 2009)
- Musk fragrances in humans (Hutter et al., 2009)

# Adverse Ecological Effects?

## Bacteria

- Reduced soil microbial activity
- Synergistic effects of mixtures
- Effects to planktonic bacteria

## Plants

- Inhibited photosynthesis of microalgae
- Shifts in algal community structure
- Sulfanamide antibiotics disrupt folate biosynthesis (herbicidal effects)

## Animals

- Effects to tadpole development
- Abnormal development in clams and decreased larval survival
- Drug mixtures inhibited growth of human embryonic cells
- Renal failures in vultures (diclofenac)

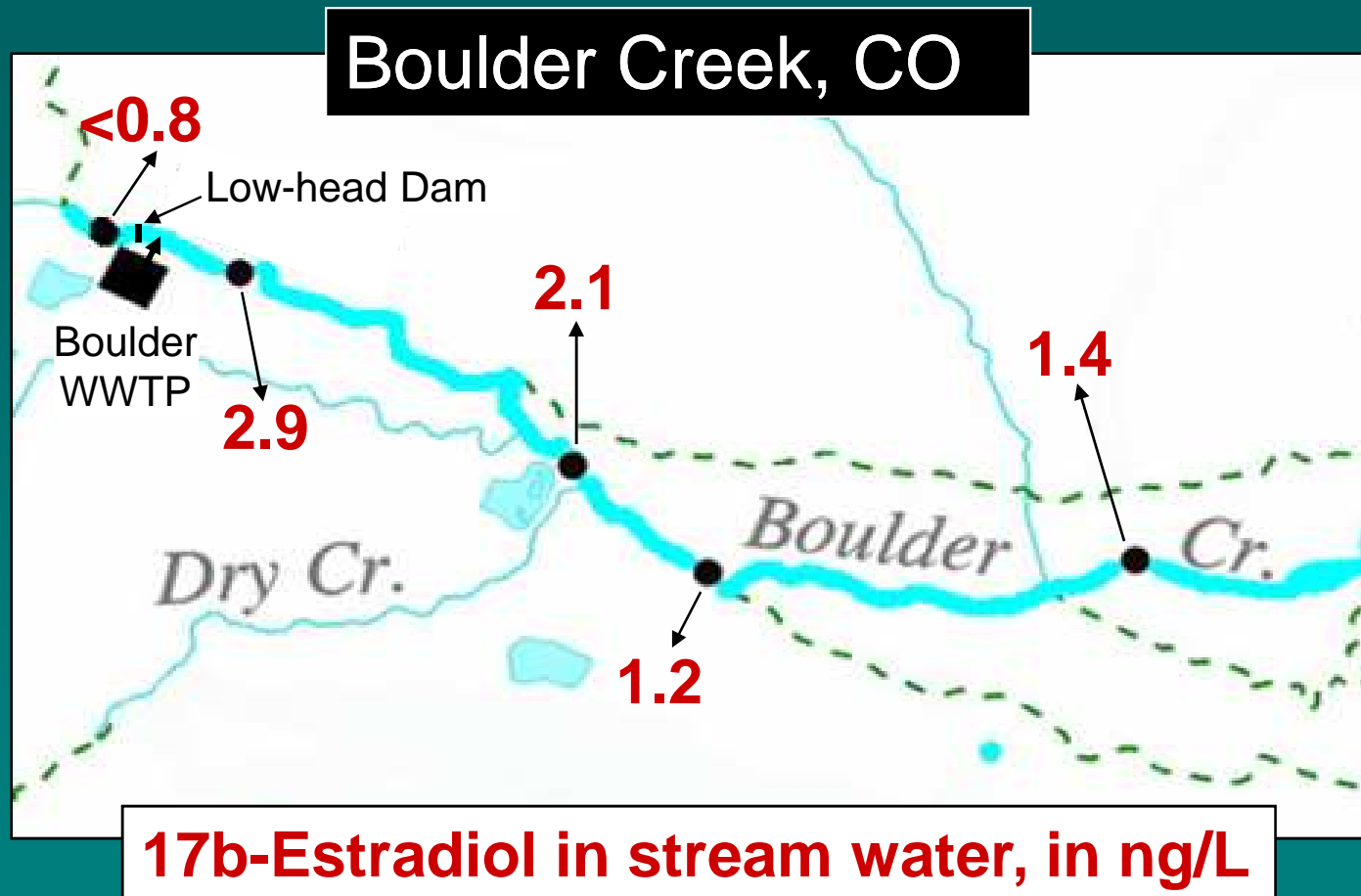
# Endocrine Disruption

*Can exposure to EDCs cause population-level effects on fish?*

*“We conducted a 7-year, whole-lake experiment at the (ELA) in northwestern Ontario, Canada, and showed that chronic exposure of fathead minnow... to low concentrations (5–6 ng/L) of ...17-ethynylestradiol led to feminization of males ... as evidenced by intersex in males and altered oogenesis in females, and, ultimately, a near extinction of this species from the lake.”*

*Kidd et al., 2007*

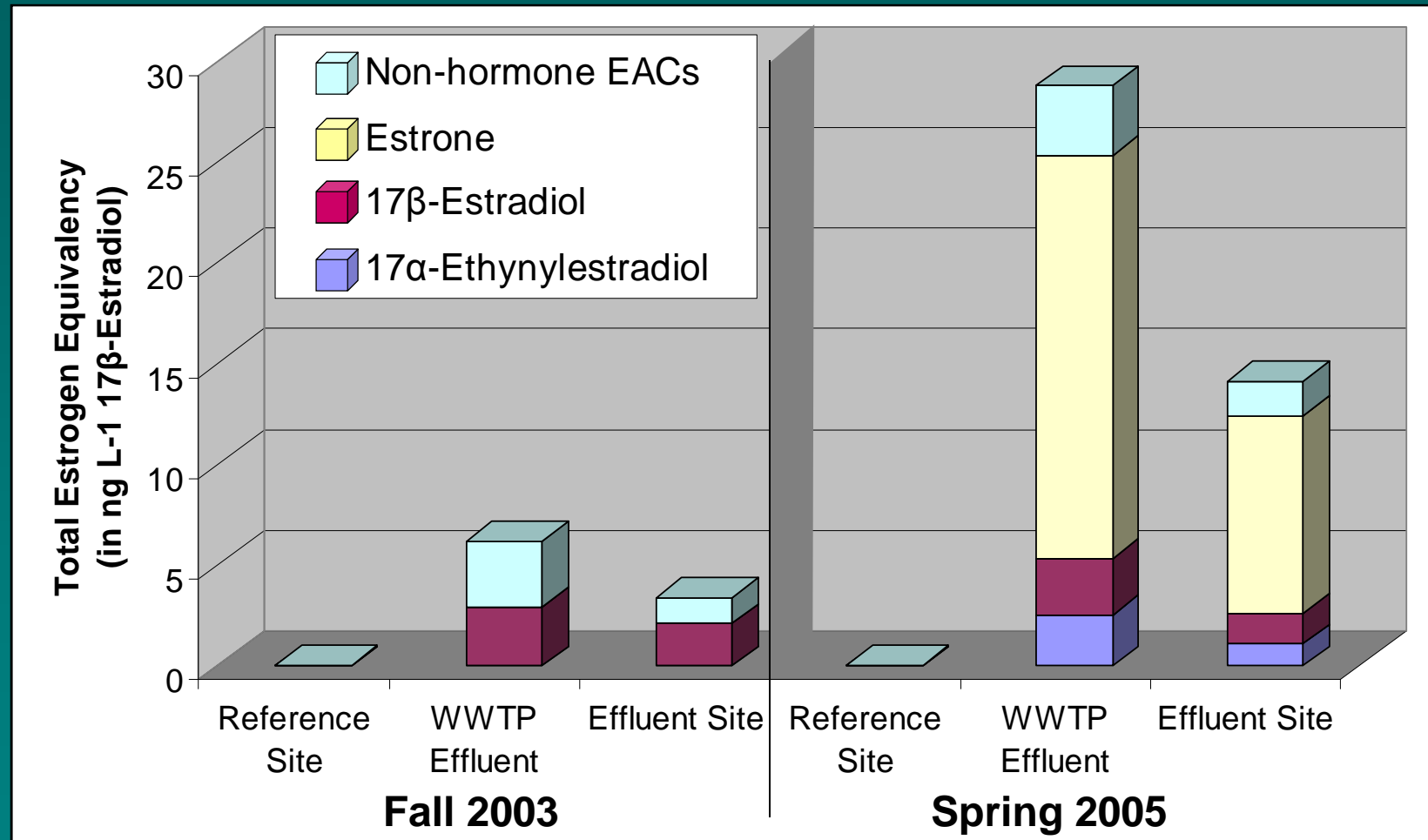
# Endocrine Disruption: A Case Study



*Vajda et al., 2008*



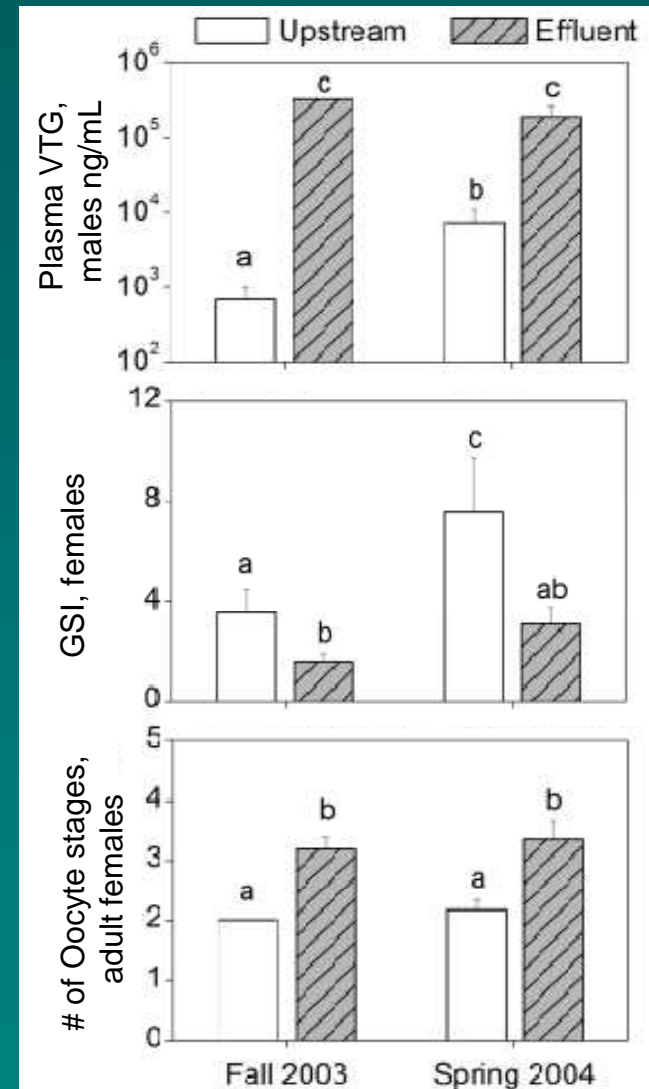
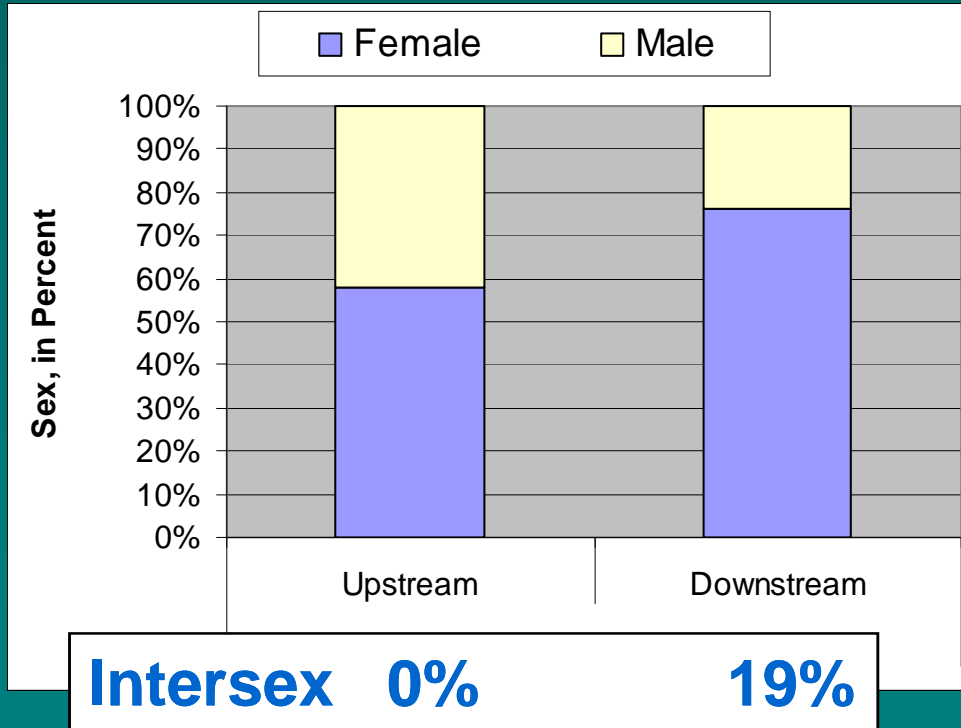
# Estrogenicity of Boulder Effluent & Boulder Creek



*Vajda et al., 2008*

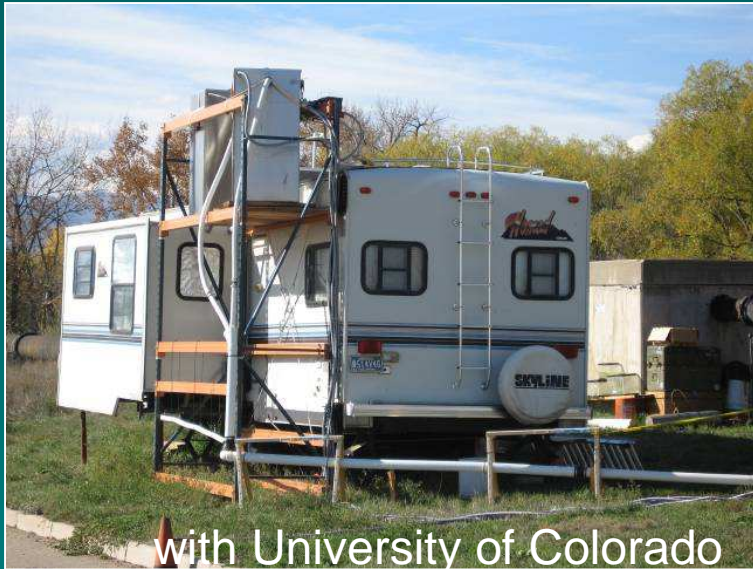
# Endocrine Effects, Boulder Creek, CO

## White Sucker



*Vajda et al., 2008*

# An Approach to Linking Chemical Exposure and Intersex

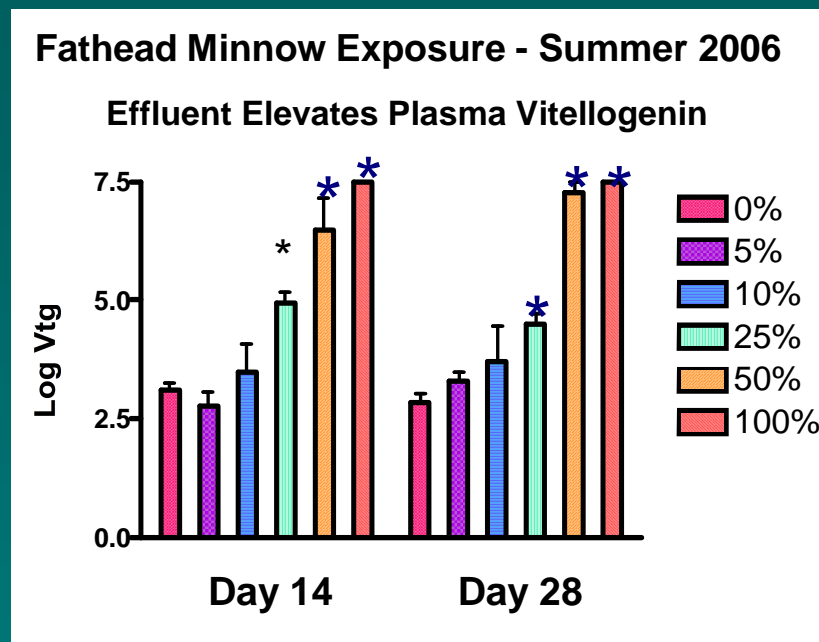
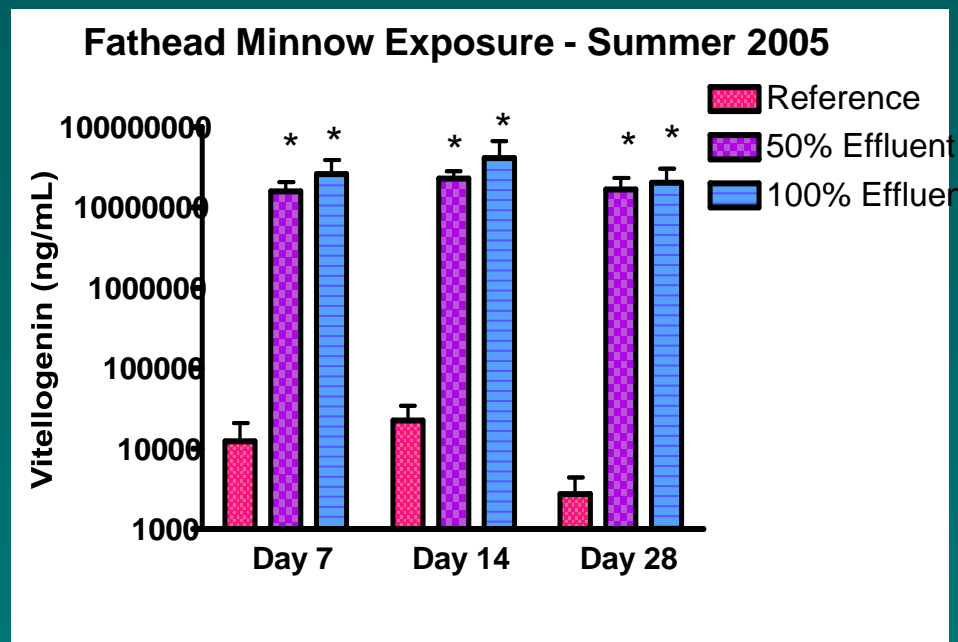


with University of Colorado

On Site - uses actual stream waters with controlled photo-period and water temp.

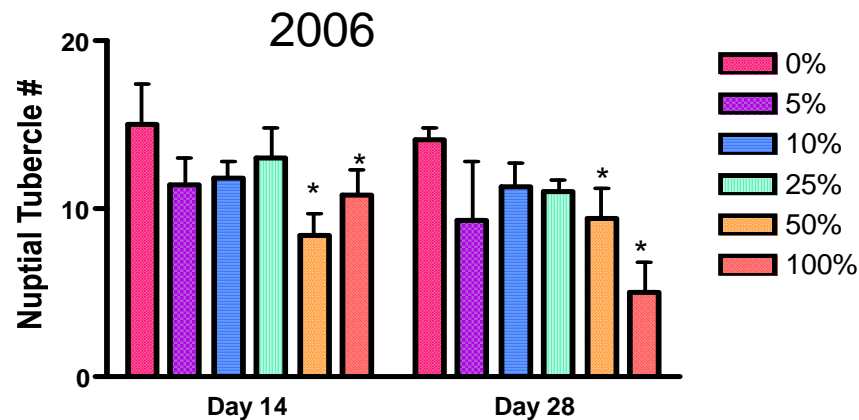
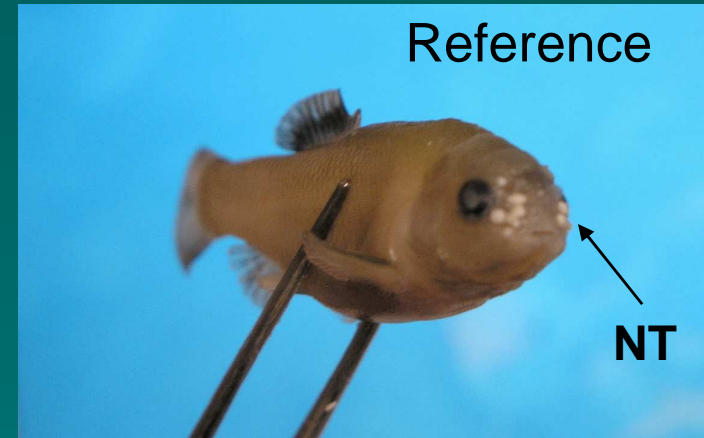
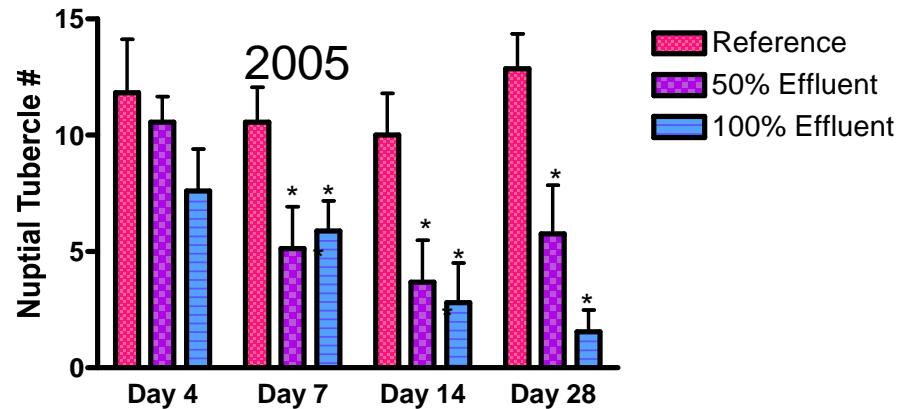


# Effluent Elevates Plasma Vitellogenin



Significant main effect of exposure ( $P < 0.0001$ )

# Effluent Reduces Nuptial Tubercle Expression



Significant effect of exposure ( $P < 0.0001$ )



USGS

# New Research for 2009 and Beyond

Source            Receptor

Method Development: Hormone metabolites, phytoestrogens, pesticide adjuvants, algal toxins, pharmaceutical degradates, nanoparticles...

Occurrence: Large datasets – 10 years of emerging contaminant data, national-scale source-water assessments, drinking water...

Sources and Pathways: Animal Feeding Operations...

Fate and Transport: Natural Assimilative Capacities of Watersheds and Aquifers - National Parks and elsewhere...

Effects: Endocrine disruption, antibiotic resistance, other modes of action...



# Acknowledgements

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Dave Alvarez, Columbia MO

Vicki Blazer, Kearneysville WV

Lisa Fogarty, Lansing MI

Frank Chapelle, Columbia SC

Steve Zaugg, Denver CO

Emerging Contaminant Project  
*[toxics.usgs.gov/regional/emc/](http://toxics.usgs.gov/regional/emc/)*

METCALF & EDDY | AECOM



Plus more....