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science for a changing world

Pharmaceuticals in the Environment: *What we know and need to know*

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U.S. Geological Survey

Chemicals of Emerging Environmental Concern: E*merging Contaminants*

Not Just Pharmaceuticals!

Chemicals that:

- ***interact*** in their affect on organisms, &
- ***co-occur*** in the environment.

Modes of Action with Chemical Interactions

- Endocrine Disruption (biogenic hormones, synthetic hormones, hormone mimics & blockers)
- Antimicrobial Resistance (synthetic antimicrobials, natural antimicrobials, metals, pesticides?)

Emerging Contaminants

- Human & Veterinary Pharmaceuticals

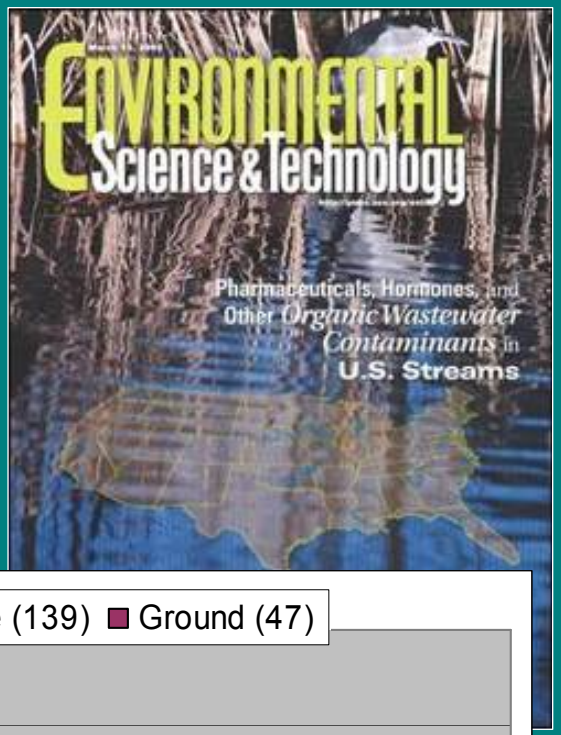
- Detergents
- Antioxidants
- Fire retardants
- Disinfectants
- Fumigants
- Fragrances
- Pesticides/ Repellants
- Industrial Chem's, HPVs
- Some Metals
- Biogenic Hormones
- Phytoestrogens
- Natural antimicrobials
- Natural pesticides
- *Degradates/ Metabolites*

Framing Research Questions

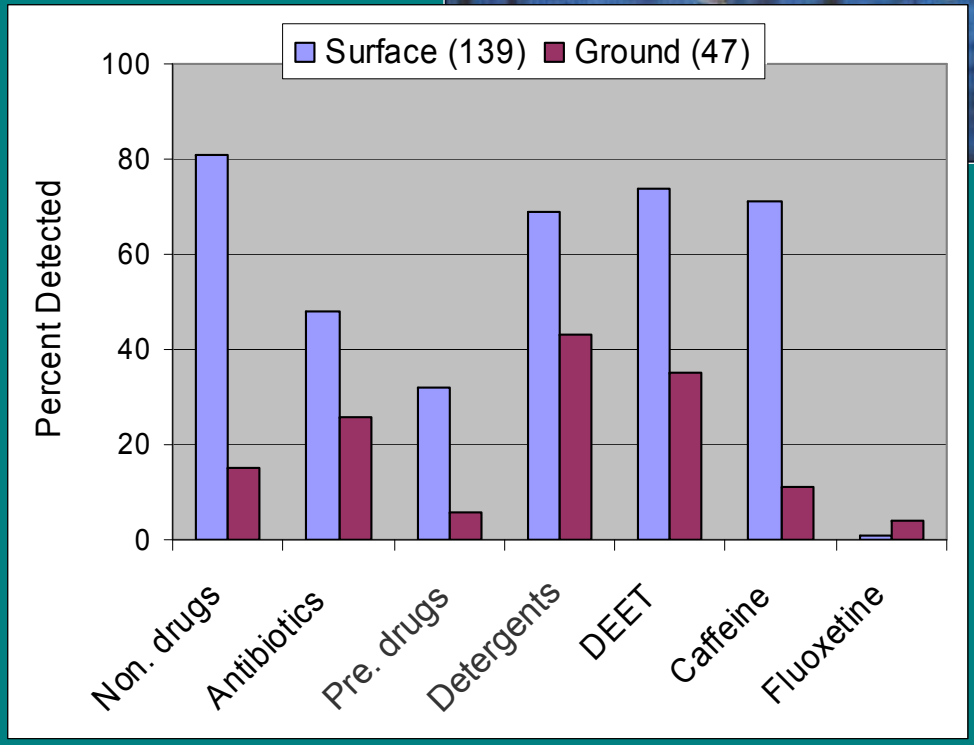
- *Are Pharm's entering our environment?*
- *What are the source pathways, their chemical signatures/loads?*
- *Are there sensitive environmental settings?*
- *Do Pharm's have adverse ecological health effects?*
- *Do Pharm's persist to finished drinking water and are they a human health risk?*
- *How can we minimize their entry to the environment or remove them?*

Are Emerging Contaminants entering our natural environment?

National Surveys of "Susceptible" Waters



- *High density* of population and animal production.
- Present in water at *sub-ppb concentrations*
- Present in complex *mixtures*.
- Greater levels in streams than wells



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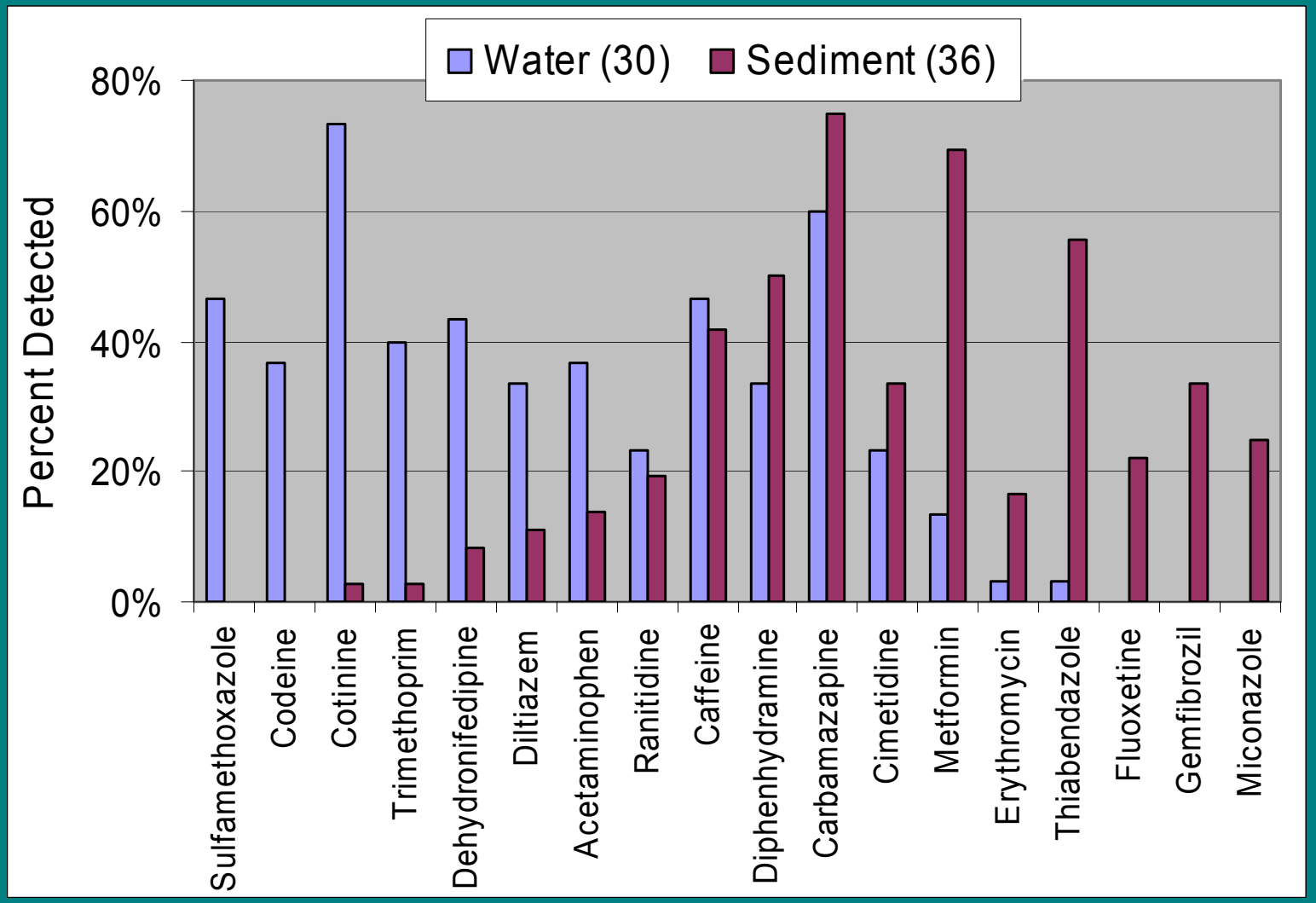
Kolpin, et al., 2002; Barnes et al., 2008

Don’t just look in stream waters!



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Furlong, et al., 2003

Measurement Capabilities

- Clofibric Acid (Buser 1998)
- 32 drugs in German WWTPs *(Ternes 1998)*
- 45 drugs in US Rivers (Kolpin et al. 2002)

- amphetamines
- antibiotics
- antidepressants (SSRIs)
- antiphlogistics
- antivirals
- barbiturates
- beta-blockers
- Ca channel blocker
- contraceptives
- cytostatics
- fibrates
- glucocorticoids
- muscle relaxants
- opioids

What are the source pathways to the environment and their chemical signatures/loads?

Human Source Pathways?

- WW Treatment Plants
- Domestic Septic Systems
- Land Application
- Industrial/Commercial Discharges
- Landfills
- Water Reuse

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Animal Source Pathways?

- Grazing
- AFOs/CAFOs
- Waste lagoons
- Land application
- Processing
- Aquaculture
- Pets

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WWTP Discharges to Streams

- Complex chemical mixtures.
- Multiple upstream WWTP discharges.
- Significant % WW in some streams (arid or urbanized watersheds).

ECs in Biosolids Destined for Land App

Carbon Norm. Concentration (μg/kg,10-40% C)

	Range	Median
Carbemazepine	15-1,200	68
Diphenhydramine	32-22,000	340
Fluoxetine	100-4,700	370
Triclosan	1,170-32,900	10,200

- Biosolids from 9 sites
- 53 (of 87) ECs detected
- 30 to 45 in each biosolid
- 25 in all samples

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Kinney et al., 2006

Septic Systems

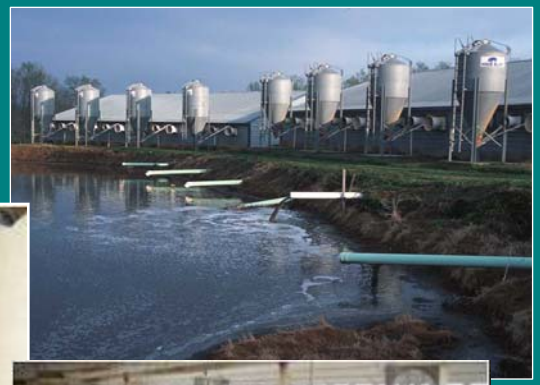
ECs found in septic wastewaters and adjacent groundwater *(Swartz et al., 2006; Carrara et al., 2008)*

Higher levels in commercial than domestic septics (restaurants, convenience stores, retail centers, schools, veterinary hospitals) *(Conn et al., 2006)*

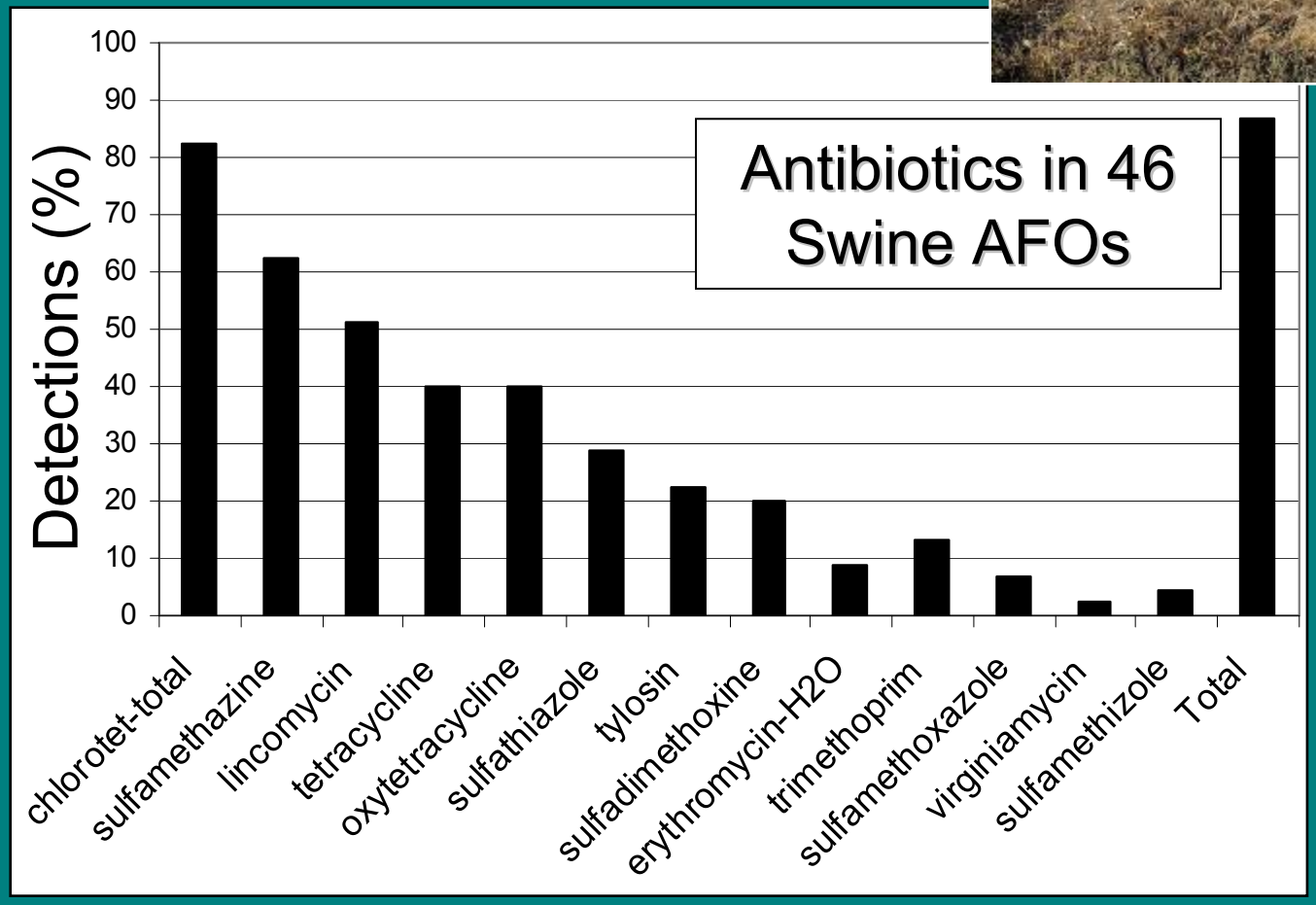
Conc. Animal Feeding Operations

- Large facilities
- Prophylactic doses
- Antibiotics, growth promoters, estrus modulators, …

Manure (kg/day)	
Human	1.5
Cow	30
Hog	4
Sheep	1.5
Chicken	0.14



Antibiotics in Swine Lagoons



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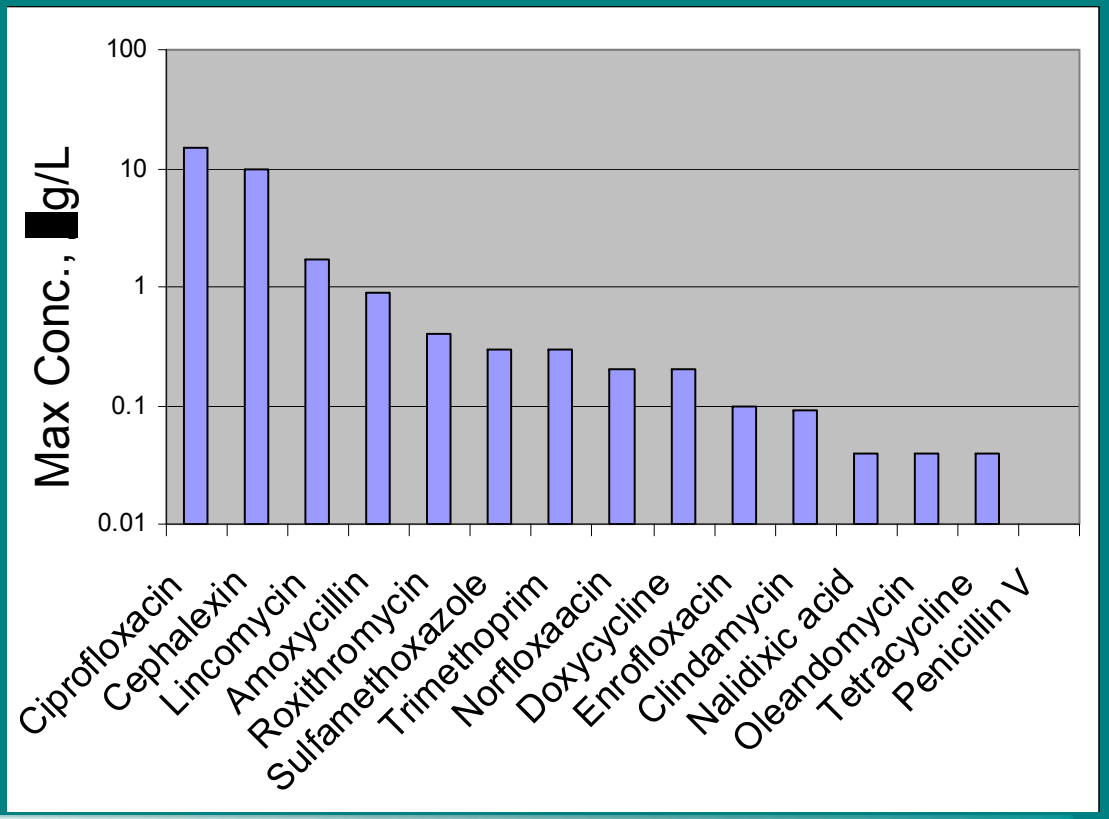
Meyer et al., 2003

Are there sensitive environmental settings?

Hospital Effluents (Antibiotics)

3 Hospitals in Southeast Queensland, Australia

16 of the 27 antibiotics detected.



Watkinson et al., 2009

Pharm. Manufacturing Facilities

WWTP near Hyderabad India

- Receives effluent from 90 bulk drug manufacturers.
- Samples on consecutive days.

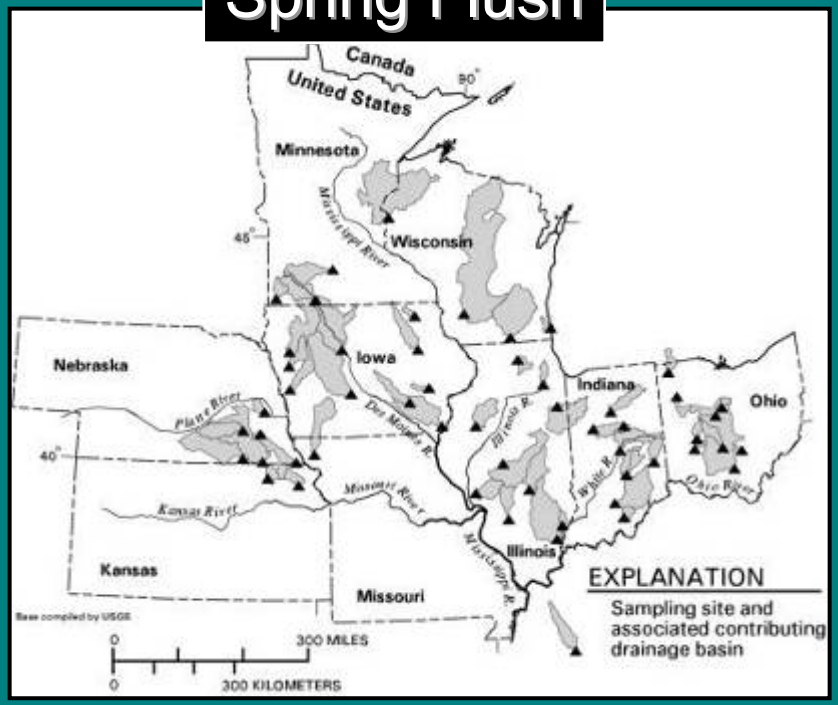
Active Ingredient	Drug Type	Range (µg/L)
Ciprofloxacin	antibiotic	28,000-31,000
Losartan	angiotensin II receptor antagonist	2,400-2,500
Cetrizine	H_1-receptor antagonist	1,300-1,400
Metoprolol	B_1-andrenoreceptor antagonist	800-950
Enrofloxacin	Antibiotic	780-900
Citalopram	SSRI	770-840
Norfloxacin	antibiotic	390-420
Lomefloxacin	antibiotic	150-300
Enoxacin	antibiotic	150-300
Ofloxacin	antibiotic	150-160

Larsson et al., 2007

Hydrologic Events

Midwest Floods, Spring '08

Spring Flush



21 herbicides, 27 degradates, 36 antibiotics in 51 Midwest Streams

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Scribner et al., 2003

Animal Waste Lagoon Failure

Midwest Headwaters Stream

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Do EC's have adverse ecological health effects?

EC Uptake in Organisms

Plant Tissue

- *Oxytetracycline* in alfalfa (Kong et al., 2007).
- *Oxytetracycline, flumequine & oxolinic acid* in bryophytes (Delepee et al., 2004).
- *Trimethoprim in* carrots & lettuce (Boxall et al., 2006).
- *Sulfamethazine* in corn, lettuce, potatoes (Dolliver, et al., 2007).

Animal Tissue

- *Fluoxetine* in bluegill, catfish, carp, crappie (Brooks et al., 2005).
- *Gemfibrozil* in goldfish (Mimeault et al, 2005).
- *Triclosan & Methyl-triclosan* in carp (Leiker et al., 2008).
- *Trimethoprim & Triclosan* in earthworms (Kinney et al., 2008).

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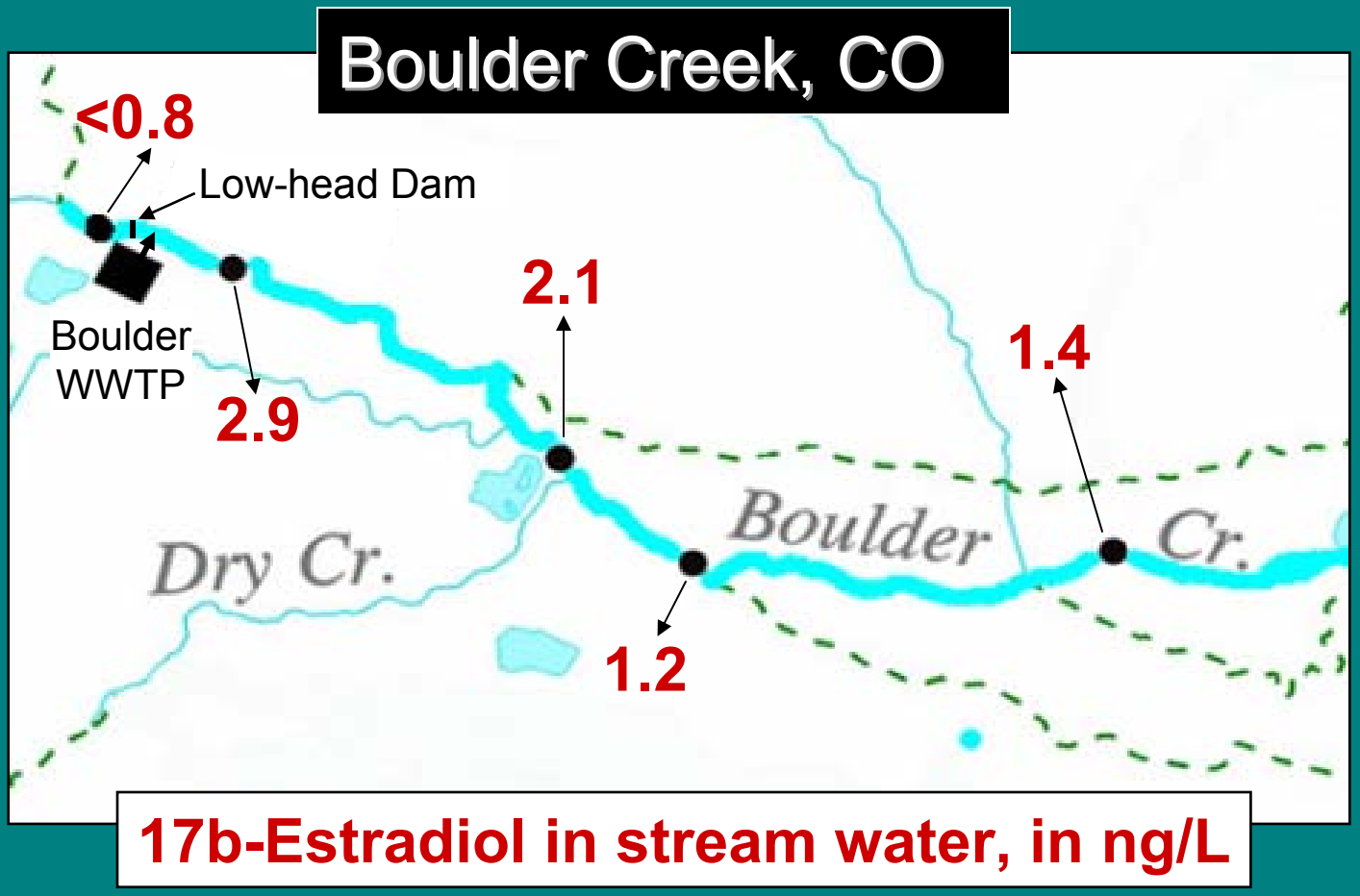
Ecological Effects

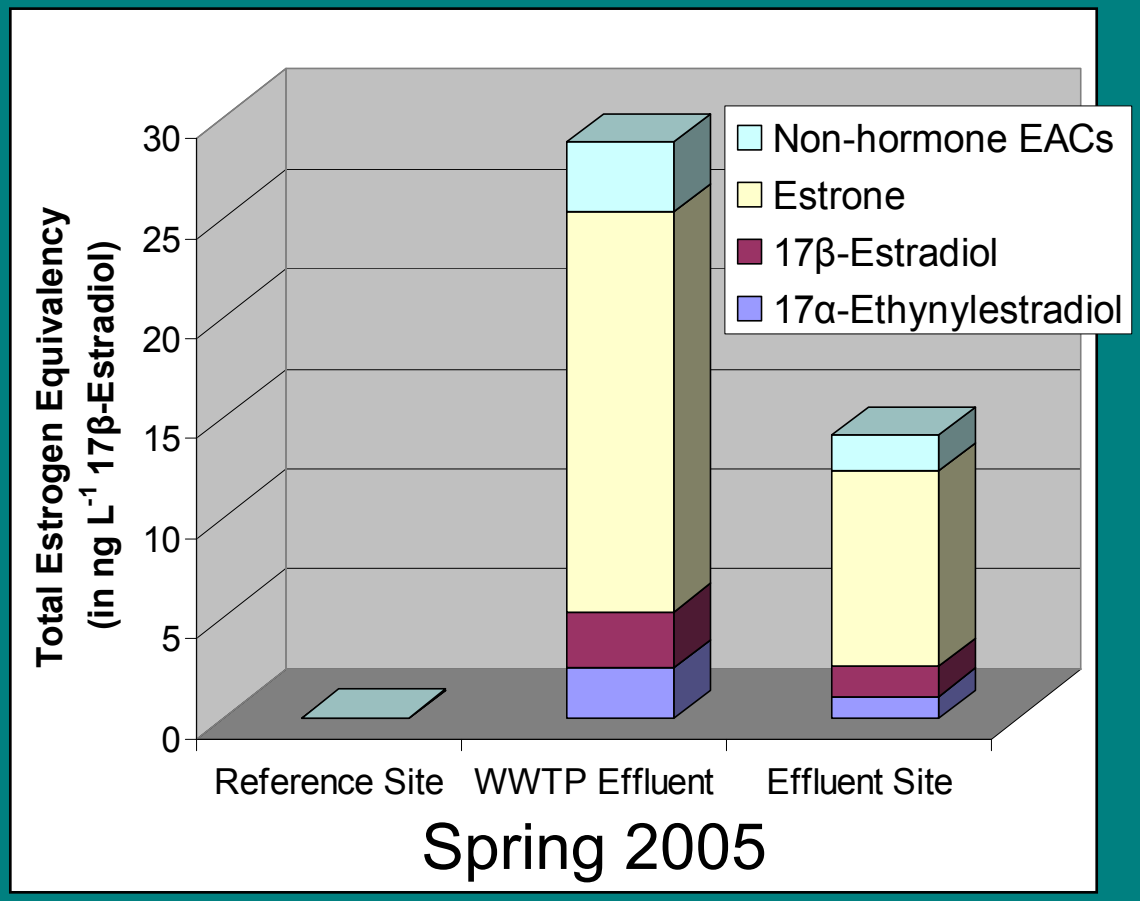
- Antibiotics: Reduced soil microbial activity at env. concentrations (Costanzo et al., 2005; Thiele-Bruhn and Beck, 2005).
- Diclofenac (NSAID): Consumption of diclofenac-treated meat caused renal failure in *vultures* (Oaks et al., 2004).
- Ciprofloxacin, triclosan, Tergitol NP 10: shifts in algal community structure (Wilson et al., 2003) .
- Drug Mixtures 13: Inhibited growth of human embryonic cells at environmental levels (Pomati et al., 2006, 2008).
- Fluoxetine: Affected reproduction in freshwater molluscs -- water-sediment exchange (Sanchez-Arguello et al., 2009).
- Antidepressants: (environmental levels) Affected predator avoidance behavior of larval fathead minnow (*McGee et al. 2009).*
- 4-nonylphenol: (environmental exposures) Impaired reproductive potential of male fathead minnows. (*Schoenfuss et al., 2008).*
- Alkylphenolethoxylates: (environmental mixtures) Reduced reproductive competence in male fathead minnows (*Bistodeau et al., 2006).*
- Sewage Sludge: Affected bone homeostasis in sheep (Lind et al., 2009).

Endocrine Disruption: A Case Study



Vajda et al., 2008

Estrogenicity of Boulder Effluent & Boulder Creek



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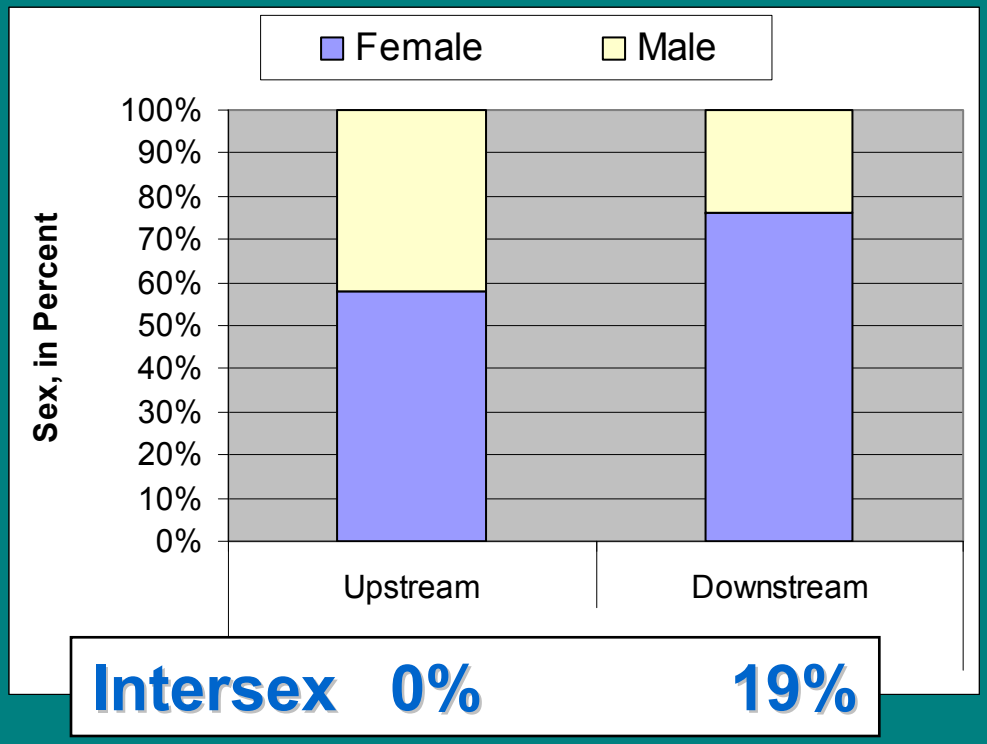
Vajda et al., 2008

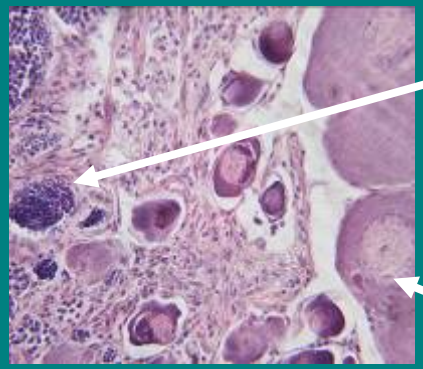
Endocrine Effects in Boulder Ck (White Sucker)



Intersex

Blood Vitellogenin

Cellular Abnormalities



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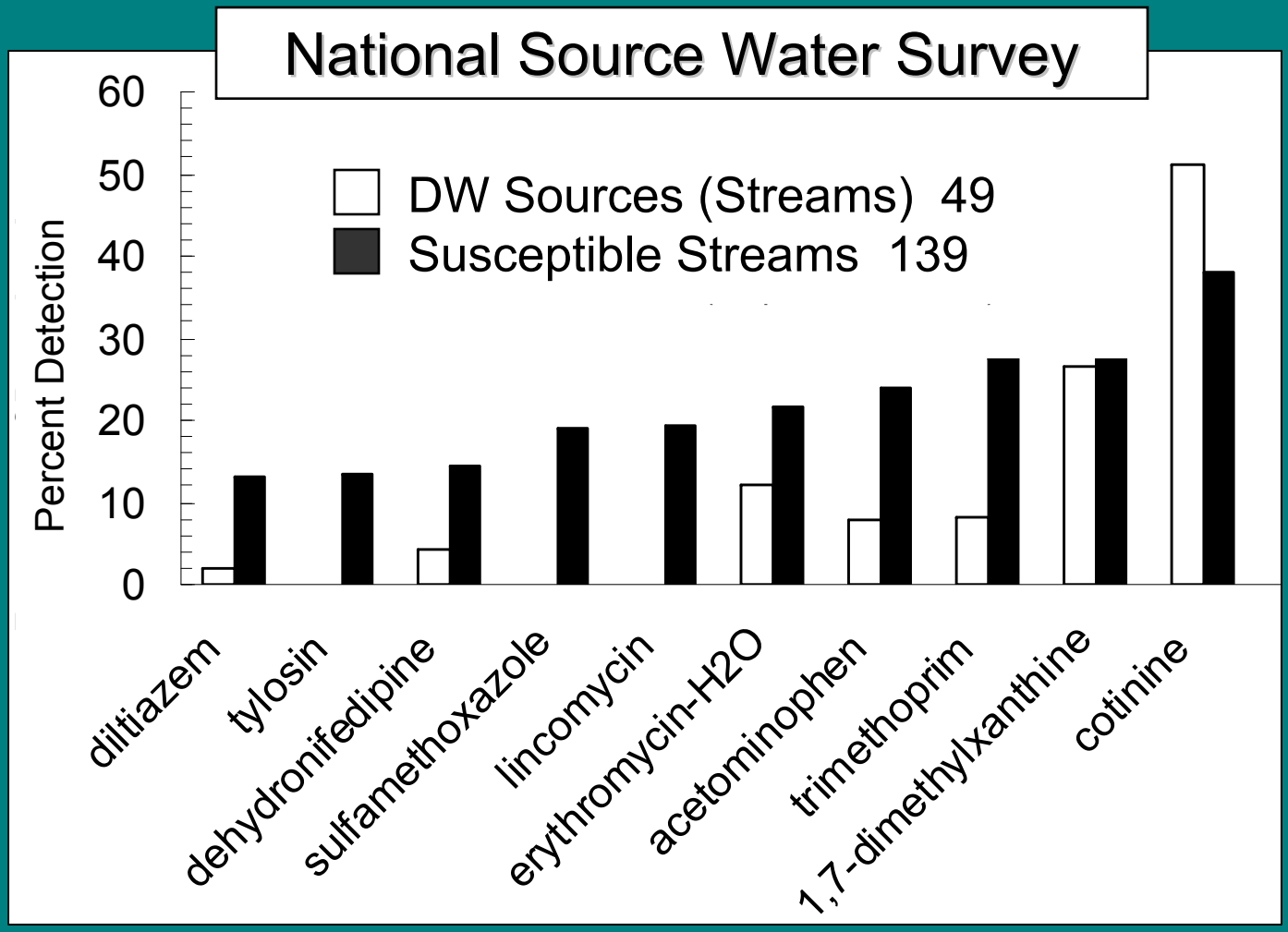
Vajda et al., 2008

Do EC's persist to finished drinking water and are they a human health risk?

Natural Dilution and Degradation



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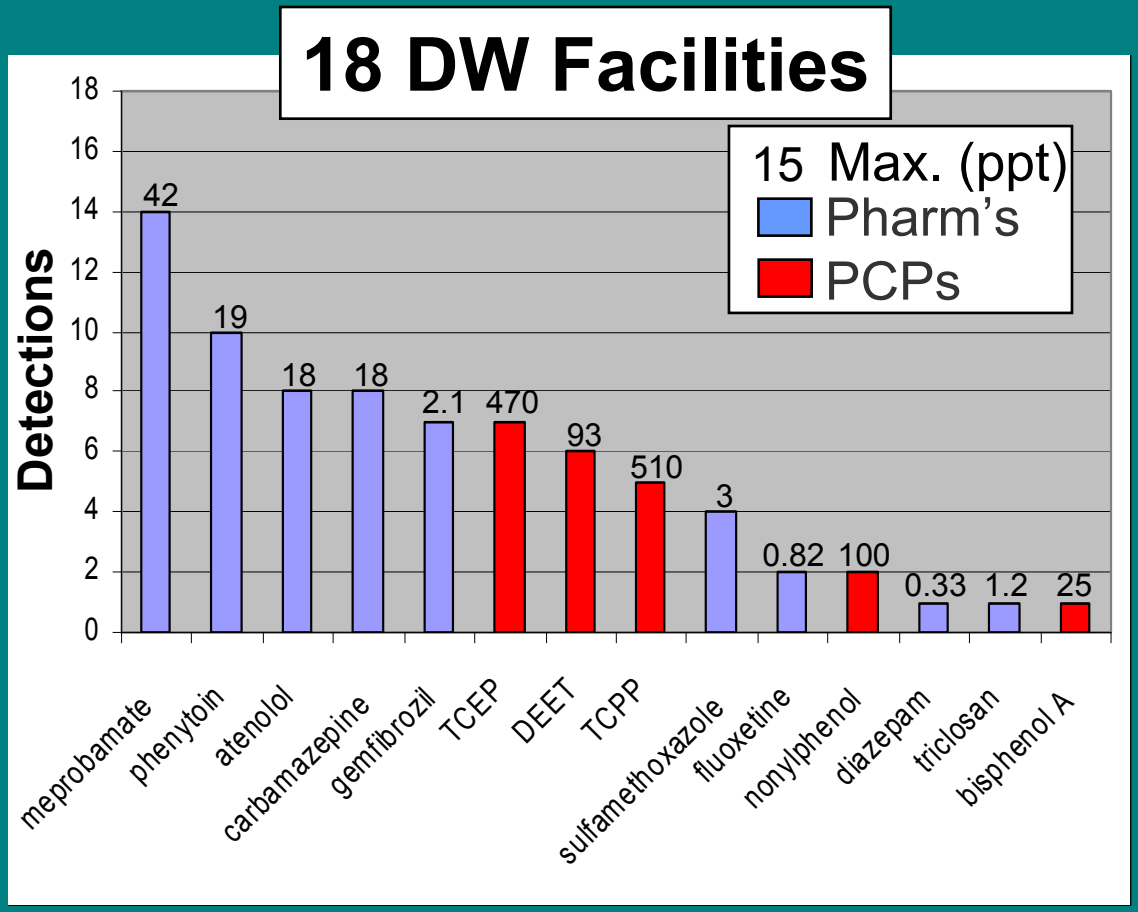
Focazio et al., 2008

ECs in Finished Drinking Water

*11 of 20 Pharm's not detected

Conducted by Southern Nevada Water Authority

Supported by AWWA Research Fnd. & WateReuse Fnd.



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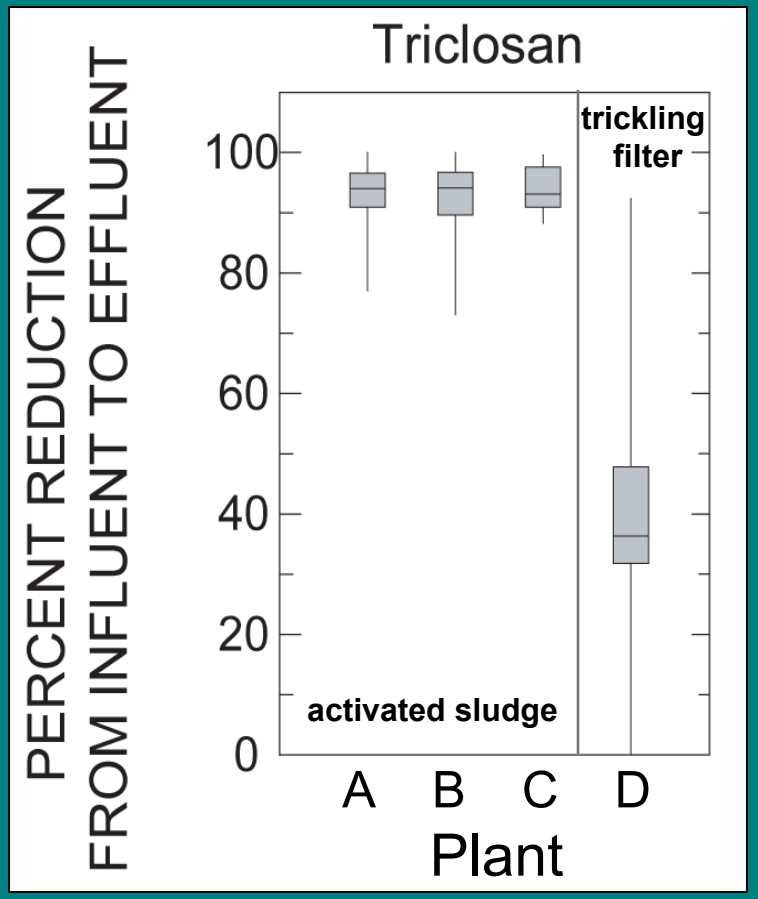
Benotti et al., 2008

Human Health Risk?

- Chronic low-level exposure.
- Exposure to chemical mixtures.
- Sensitive subpopulations.
- Can we prioritize chemicals systematically for effects studies?

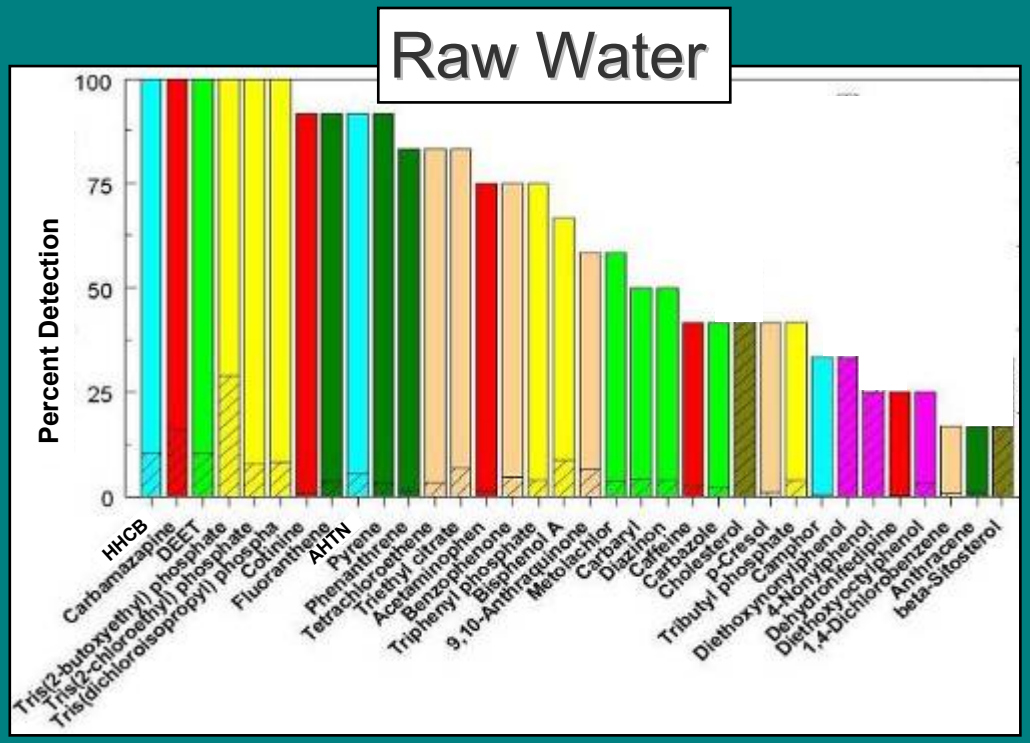
How can we minimize their entry to the environment or remove them?

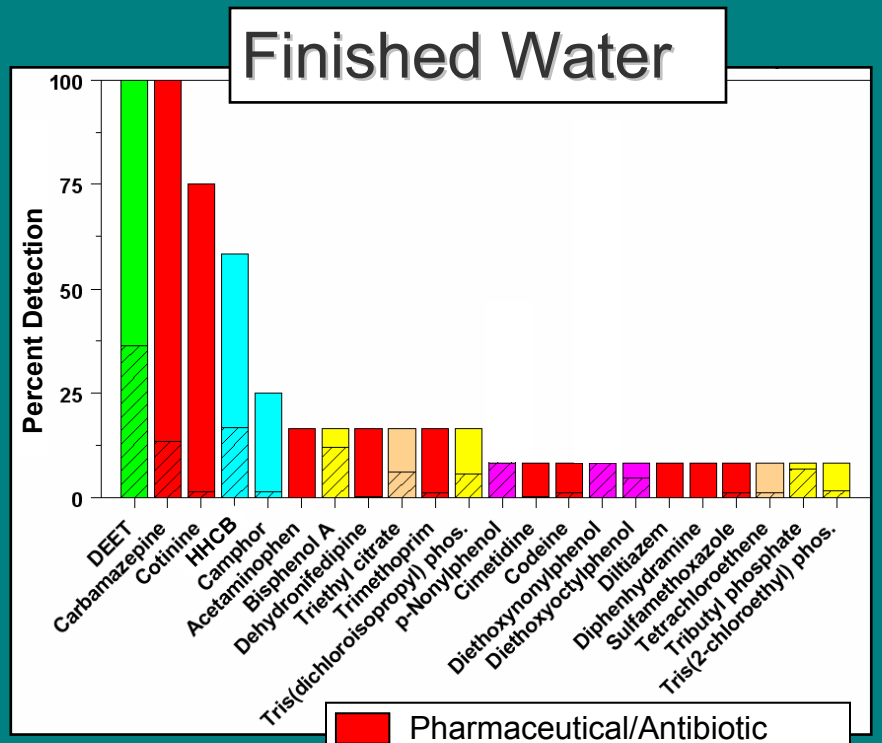
WWTPs Ability To Reduce ECs



Phillips et al., 2008

Removal in Treatment, NJ Facility





Levels Generally Reduced by Treatment with GAC Filters

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Stackelberg et al., 2004 & 2007

Thank you!

And thanks to the many researchers who provided the information presented.

For more info on USGS EC research:
http://toxics.usgs.gov