

Contaminants of Emerging Concern—An overview of the issue and new developments in environmental understanding, or...

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U.S. Geological Survey
Denver Colorado



*New Jersey Water Monitoring Council Meeting—
January 21, 2016*

What the heck are these “new” contaminants, and why should I care, really?



USA TODAY

Home News Travel Money Sports

News » Nation Troops at Risk States Lotteries

AP: Drugs found in drinking water

Updated 9/12/2008 2:02 PM | Comments 149 | Recommend 84



PUR WATER FILTRATION SYSTEM

PUR Faucet Mount Filter can remove over 99% of Pharmaceuticals*

3 Stage FILTER

99.9%



PUR® 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

BBC NEWS

Sex-change chemicals in Potomac



LET'S TALK ABOUT SEX... Sarah Jessica Parker Returns as Carrie VOGUE'S On-Set Exclusive

How Clean Is Your Water?

ESSENTIAL WEDDING GUIDE

A CITY, A HOUSE, A LOVE STORY One Woman's journey to Settling Down

WHAT TO WEAR EVERYWHERE 25 Fall Looks



COUNTERTHINK

YOU CALL THIS TERRORISM?

DON'T WORRY BOSS, WE TOOK EXTRA PRESCRIPTION DRUGS AND NOW WE'RE POISONING THE WATER SUPPLY!

CONCEPT: MIKE DOMMS ART: DAN BERGER WWW.NEWS-TARGET.COM

FACT: PHARMACEUTICALS ARE NOW BEING DETECTED IN PUBLIC WATER SUPPLIES.



FRONTLINE

POISONED WATERS

A far-reaching investigation into America's great waterways. They are in peril. There's a new wave of pollution that's killing fish, causing mutations in frogs -- and threatening human health.

Watch the full program

Join the Discussion

So What's Safe to Eat & Drink?

Weren't Our Waters Supposed to Be Cleaned Up Years Ago?

I Want to Get Involved...

Interviews | Site Map | Press Reaction | DVD/Transcript | Credits | Journalistic Guidelines | Privacy Policy

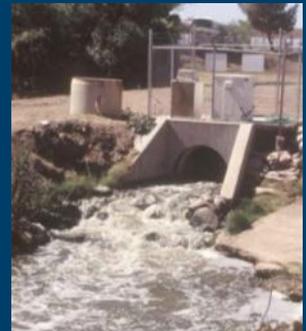
Outline

- Background understanding on contaminants of emerging concern (CECs).
- Highlights of recent USGS research on CECs, particularly on aspects connecting sources, transport, and distribution.



What are CECs? “umbrella term”

- Pharmaceuticals
- Disinfection BPs
- Mycotoxins
- Fragrances
- Detergents
- PFCs
- Pathogens
- Hormones
- Neonicotinoid Insecticides
- Phytoestrogens
- Illicit drugs
- Fire retardants
- Algal toxins
- Nanomaterials



1. We all contribute to CECs
2. Not currently regulated
3. Incomplete knowledge of fate or effects



SGS

For more than 15 years, pharmaceuticals have been of ongoing public interest...

NATURE WORLD NEWS

SECTIONS ▾

TRENDING TOPICS PREGNANCY PROSTATE CANCER HEALTHY EATING
QUANTUM PHYSICS PUBLIC HEALTH NATURE

Pharmaceutical Pollution Wreaks Havoc on Nation's Rivers

THE DENVER POST / 2002

DENVER AND THE WEST

March 13, 2002

www.denverpost.com/news

River study stirs up concerns

Little-known pollutants in S. Platte

By Leo Stein
Denver Post Environment Reporter

A federal science agency hopes to take a harder look at the South Platte after its study revealed the river's water contains a broad range of little-known pollutants such as caffeine, antibiotics, household disinfectants and hormones.

"Water reuse and recycling are becoming a big part of our water strategy," said a spokesman for the agency.

"As downstream communities turn to sources that contain treated wastewater, it will become invaluable for utilities to know what pollutants are in the water."

The study showed the levels of 95 chemicals in the South Platte River. The chemicals included caffeine, antibiotics, hormones, and household disinfectants. The study was designed to provide a snapshot of the river's water quality.

chemical compounds considered in the study. The study was designed to provide a snapshot of the river's water quality. The study was designed to provide a snapshot of the river's water quality.

In addition, the USGS specifically looked for places that chemists would be likely to show this contamination. The Commissioning location of a sample stream was also noted.

Conducted in 1999 and 2000, the study looked for 95 pharmaceuticals and other organic wastes downstream from major cities. The chemicals were selected because people use them in large quantities and because they may have human or environmental health effects.

Many of the compounds are not covered by drinking-water standards or government health advisories, and municipal wastewater treatment plants aren't designed to remove them.

THE DENVER POST / 2002

Good Housekeeping
Is Your Tap Water Safe?
<https://www.goodhousekeeping.com/health/water>

Medicines, chemicals taint water

Contaminants through

Common products polluting waterways

Beauty aids, foods, medications resist to water treatment

By Joseph B. Verrongia
Associated Press

Report: Beauty aids making rivers ugly

A government analysis shows that the nation's waterways are flooded with traces of chemicals used in beauty aids, medications, household chemicals and foods. Among the substances: perfumes, contraceptives, painkillers, insect repellent, nicotine and caffeine. Scientists say these substances largely escape regulation and defy municipal wastewater treatment. The long-term effects of exposure on humans and animals are unknown.

Mail Online

Home | U.K. Home | News | Sport | U.S. Showbiz | Femall | Health | Science | Money |

News Home | U.K. Home | News | Sport | U.S. Showbiz | Femall | Health | Science | Money |

Fish on Prozac become angry, aggressive and KILL their mates, new study finds

U.S. waterways contain traces of drugs such as Prozac, which arrive there through human excreta

- Research shows that at higher levels of exposure, the male fish kill the female fish and the female fish stop producing eggs
- Exposure of young minnows to the drug alters their genes and brain 'architecture'

By DAILY MAIL REPORTER

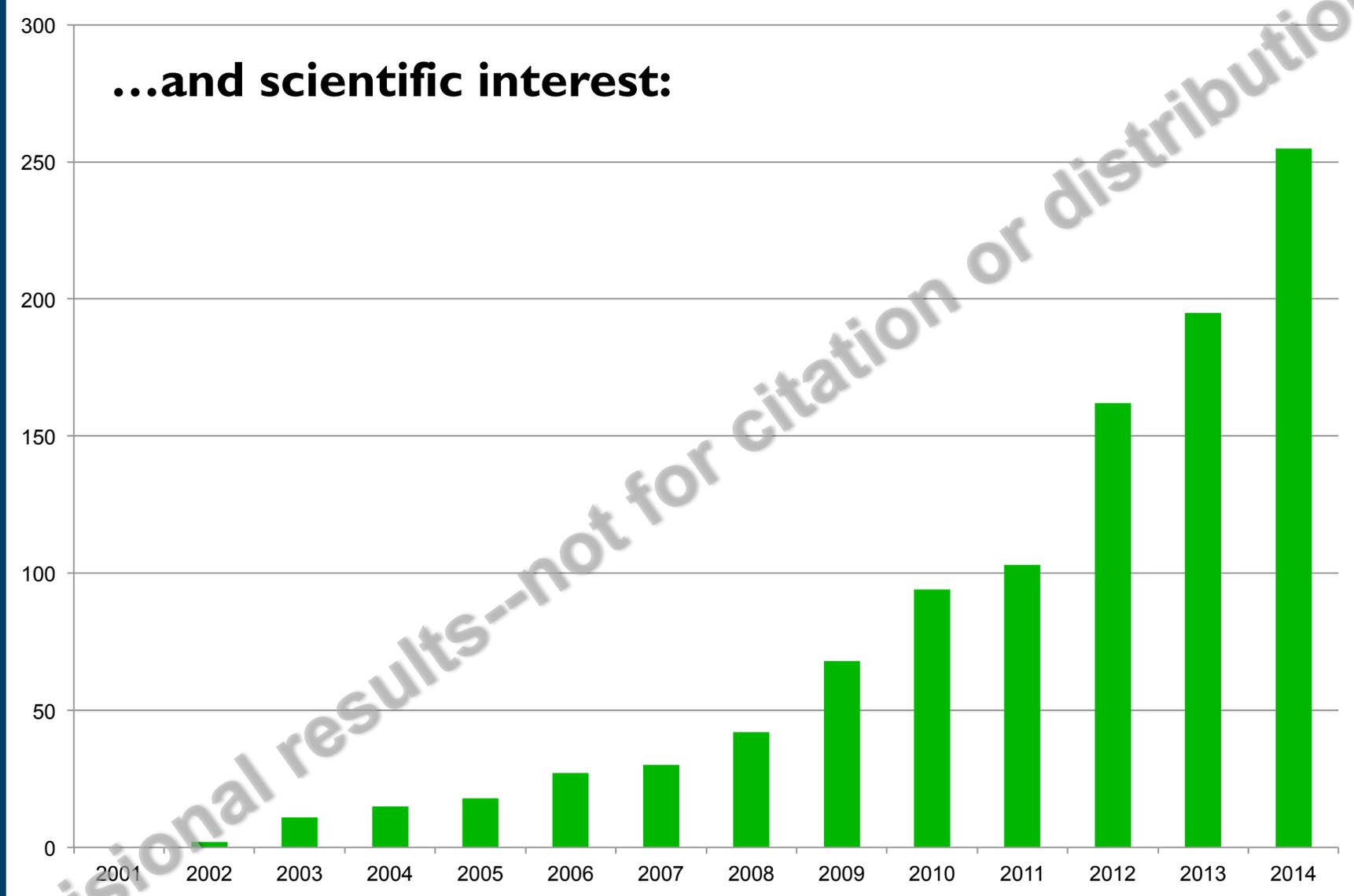
PUBLISHED: 11:52 EST, 14 June 2013 | UPDATED: 11:52 EST, 14 June 2013



AP IMPACT: Tons of Released Drugs Taint U.S. Water

Annual # of Pharmaceutical Publications

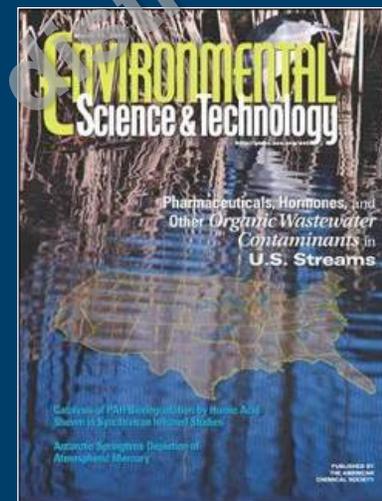
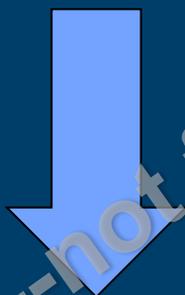
...and scientific interest:



Updated from Glassmeyer et. al. 2008

Evolution of occurrence question:

Are CECs entering
our environment?



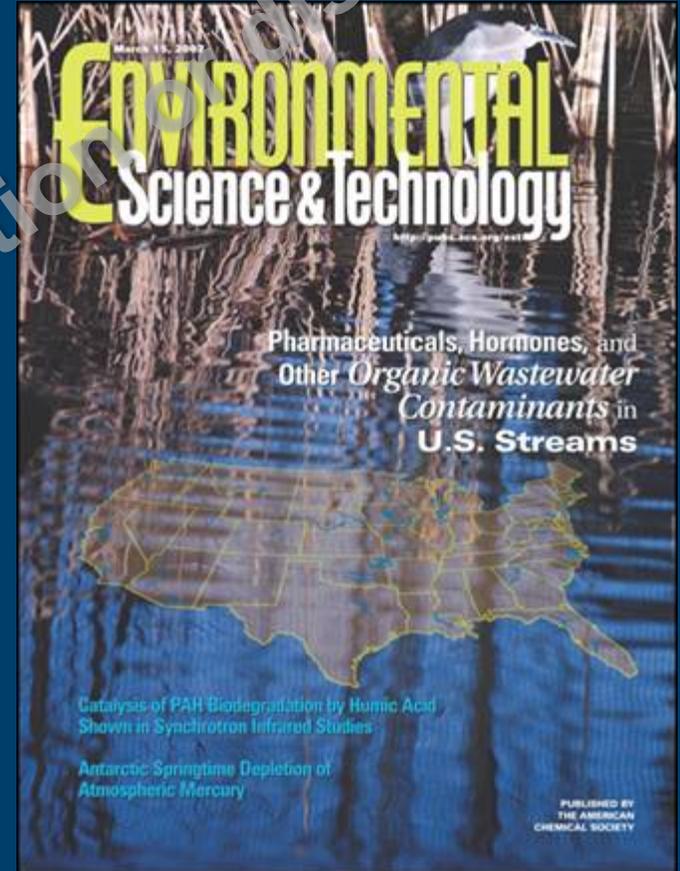
3,899 citations

What CECs are entering
our environment, and what are
their effects?

USGS

Occurrence - National Recon Studies

- Streams (1999-2000)
- Ground Water (2000)
- Sources of Drinking Water (2001)
- Streambed Sediment (2002)

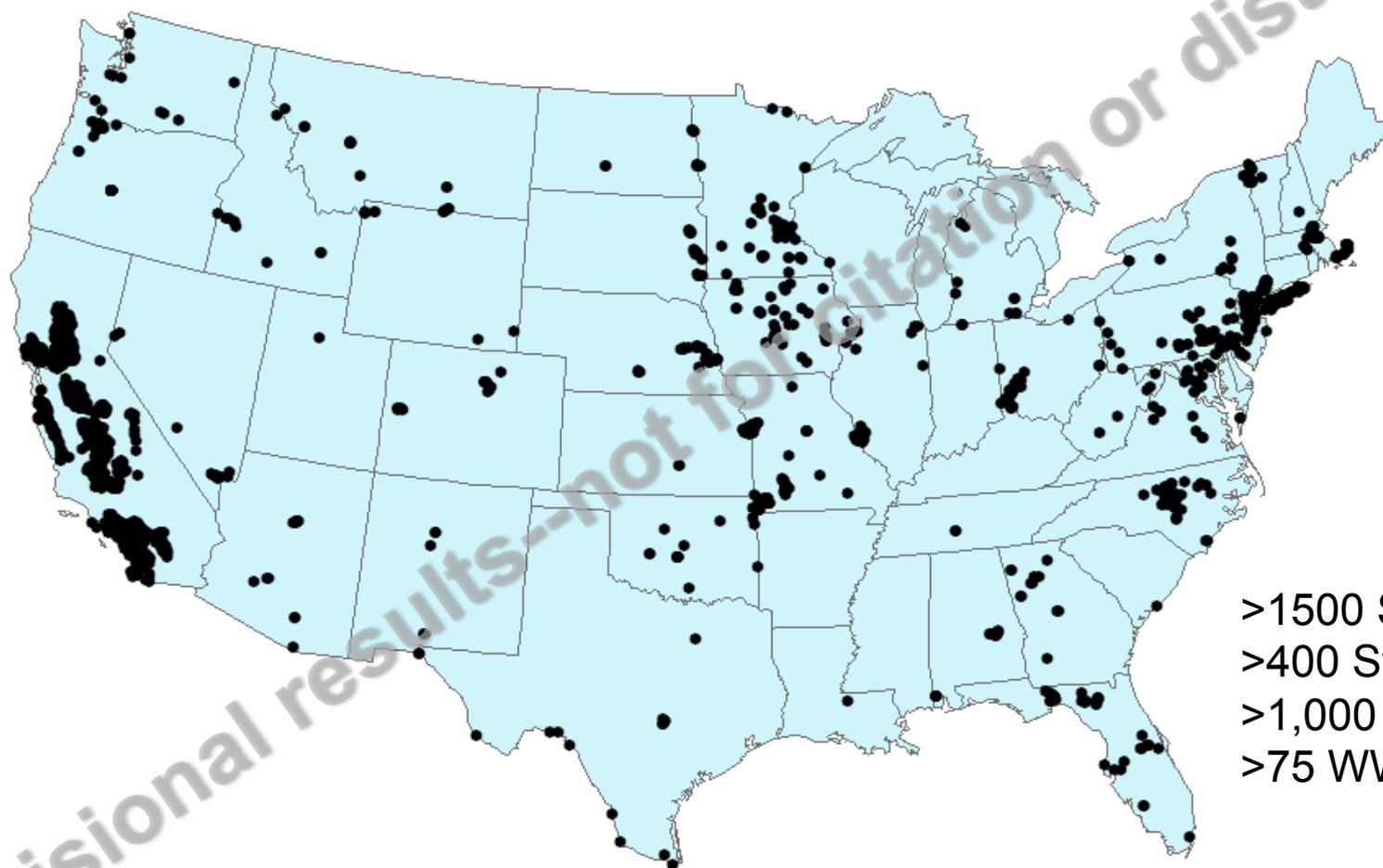


ES&T; March 15, 2002
v. 36, no. 6, p. 1202-1211



Chemicals of Emerging Environmental Concern

Sample Locations



>1500 Sites
>400 Streams
>1,000 Wells
>75 WWTPs

What have we learned about CECs?

- Present at sub-ppb concentrations in water.
 - Streams and Groundwater
- Present as complex mixtures.
- Reflect a wide range of human activities.
- Some compounds mobile and persistent.
- Depend on the media (water, solids, tissue) sampled.

**In terms of our current understanding,
we are “midstream.”**



Ongoing "Source-to-Receptor" research since 1998

Methods
Development



USGS



Sources & Pathways



Transport & Fate



Eco Exposure & Effects



Human Exposure

Human and Animal Sources

Human

- Wastewater treatment plants (WWTPs)
- Combined sewer overflows
- Onsite septic systems
- Industrial Discharge
- Landfills
- Water Reuse

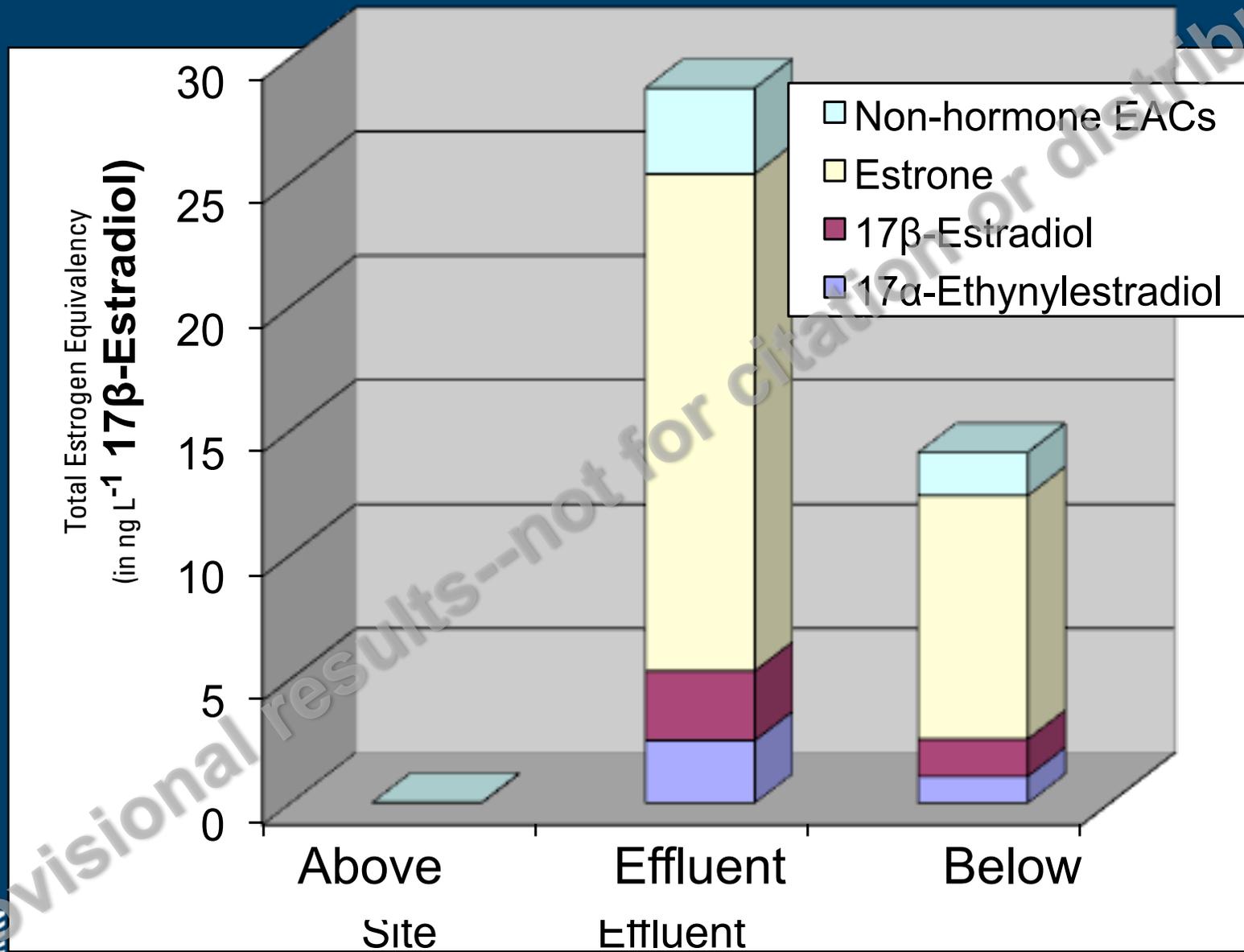


Animal

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



WWTPs: a significant CEC source



Boulder Creek, CO; from Vajda et al., 2008

Factors Affecting WWTP Effluent Concentrations

- Plant technology
- Kinds of Influent Received
- Temporal variability (e.g. diurnal, weekly)
- Hydrologic variability (e.g. events, CSOs)
- Population variability (e.g. tourism, college)



Wastewater Treatment – Critical Control Point

2007 Upgrade



Trickling Filter

Retention time ~10 hrs
Time in filter ~35 mins

Activated Sludge

Retention time ~19 hrs
Time in reactor ~10 hrs

USGS

Barber et al., 2012, *Environ. Sci. Technol.* 46

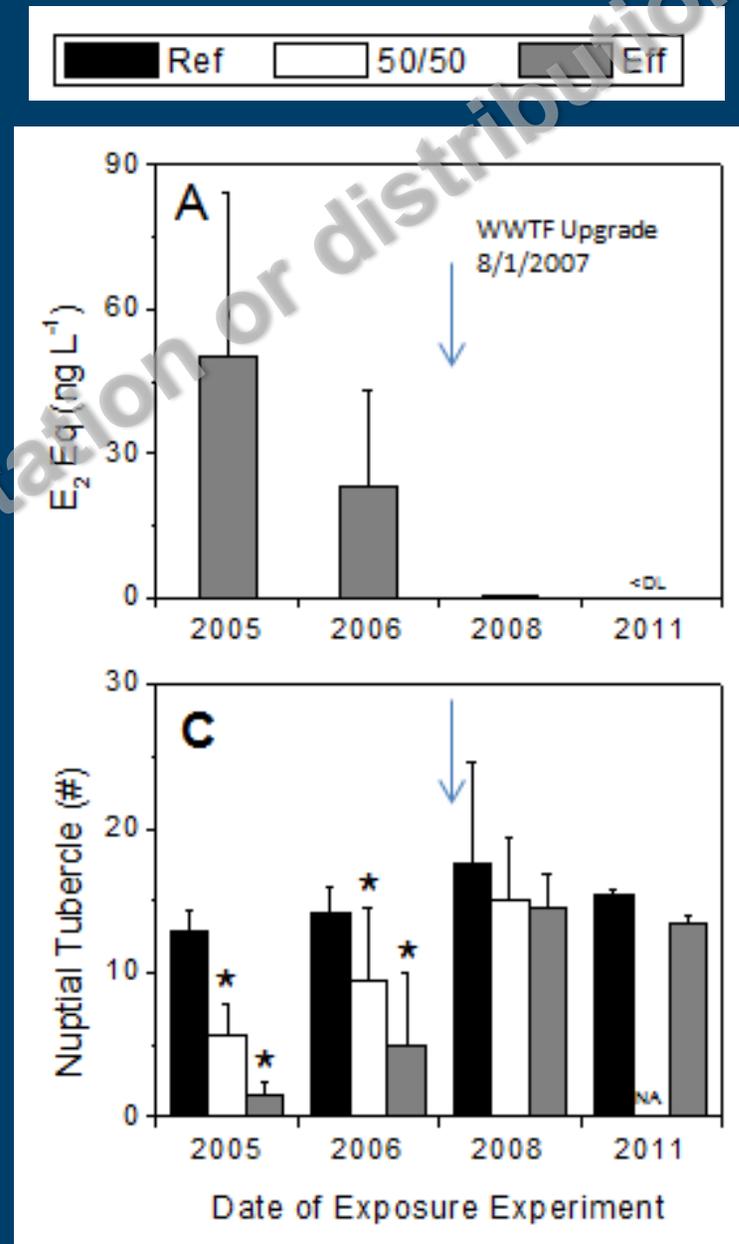
Boulder WWTP Post-Upgrade Results

Infrastructure investment:

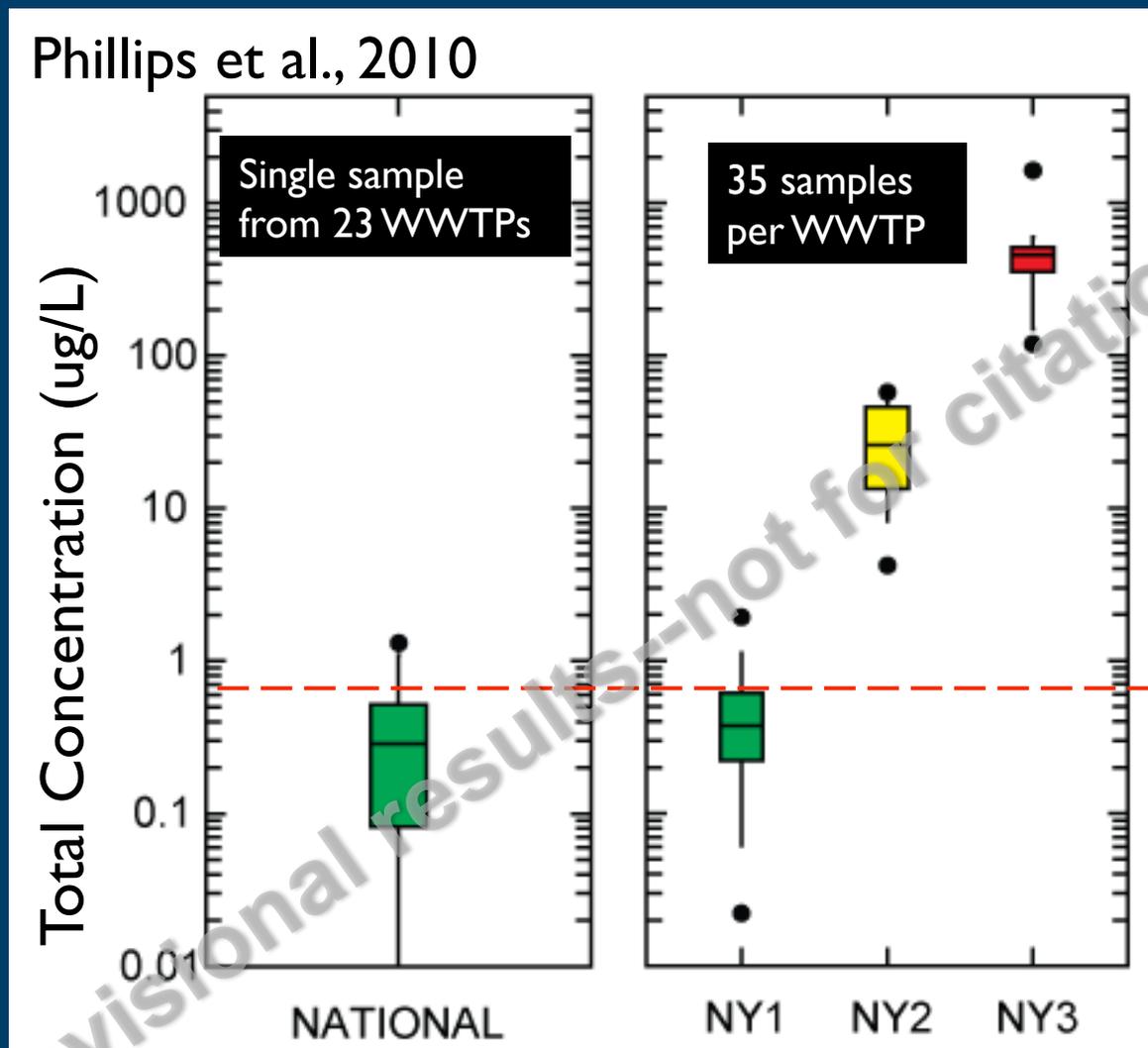
- Improved the removal efficiencies of many CECs
- Decreased the estrogenicity of discharged effluent
- Reduced endocrine disruption relative to pre-upgrade conditions



Barber et al., 2012, ES&T



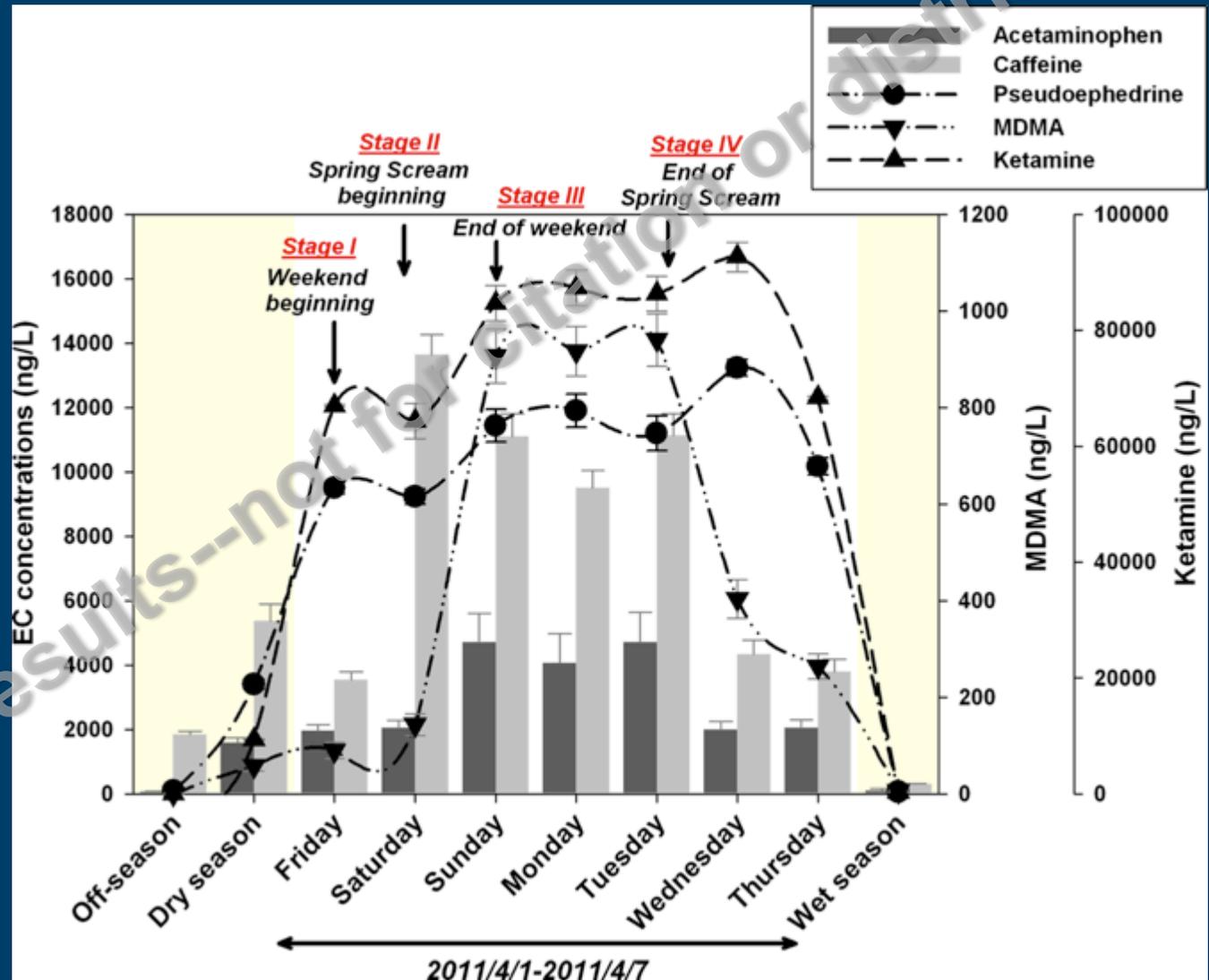
PMFs – Environmental Sources of CECs



Max Conc. (ug/L)
3,800 metaxalone
1,700 oxycodone
>400 methadone
160 butalbital
>40 phendimet.
>40 carisoprodol
4 diazepam

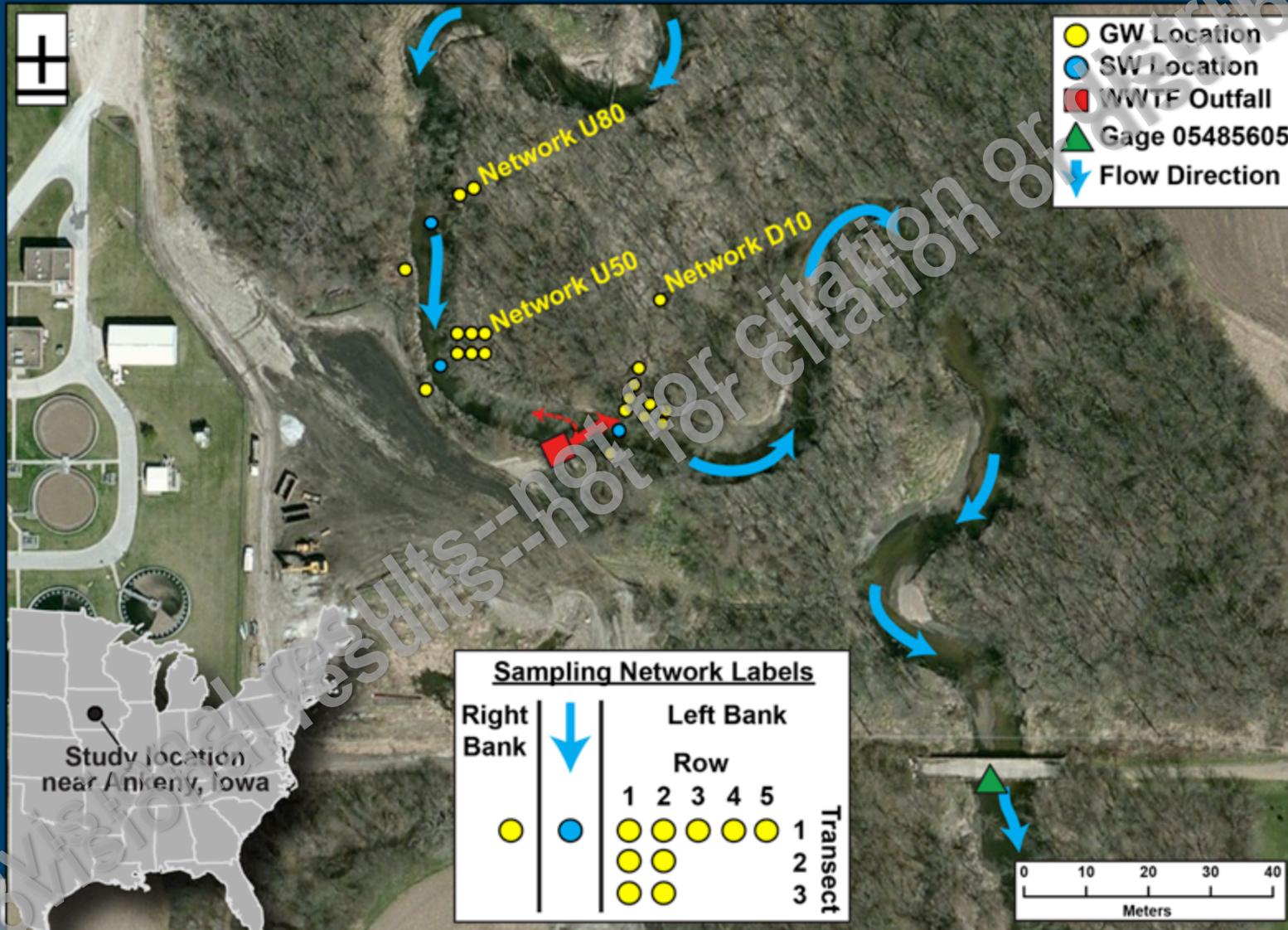
Temporal pattern in illicit drugs/control substances in WWTP influent during music festival (~600,000 people)

Spring Scream (Taiwan)

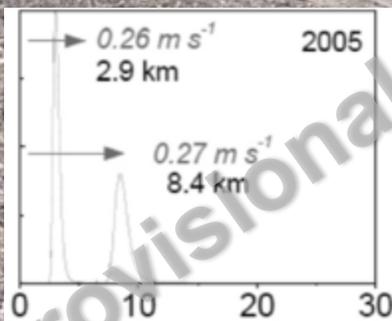
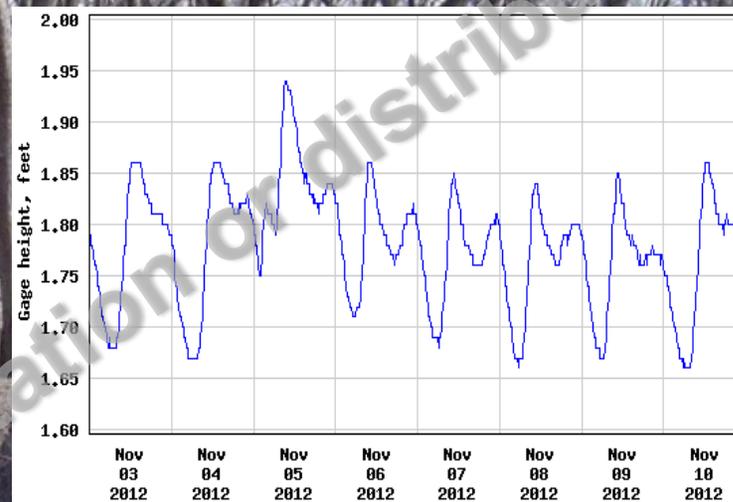
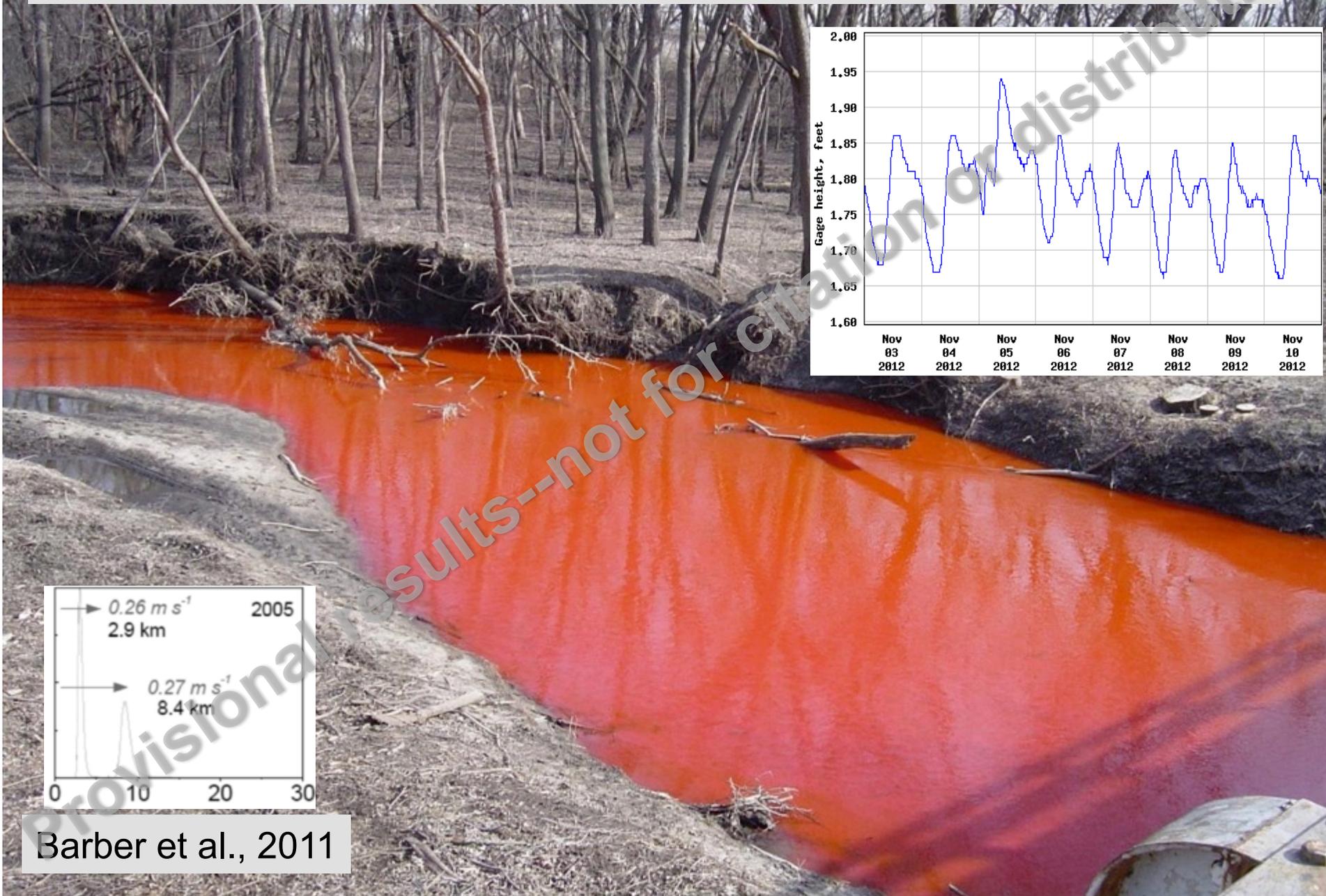


USGS

Fourmile Creek Field Lab: Lateral & Vertical Gradients

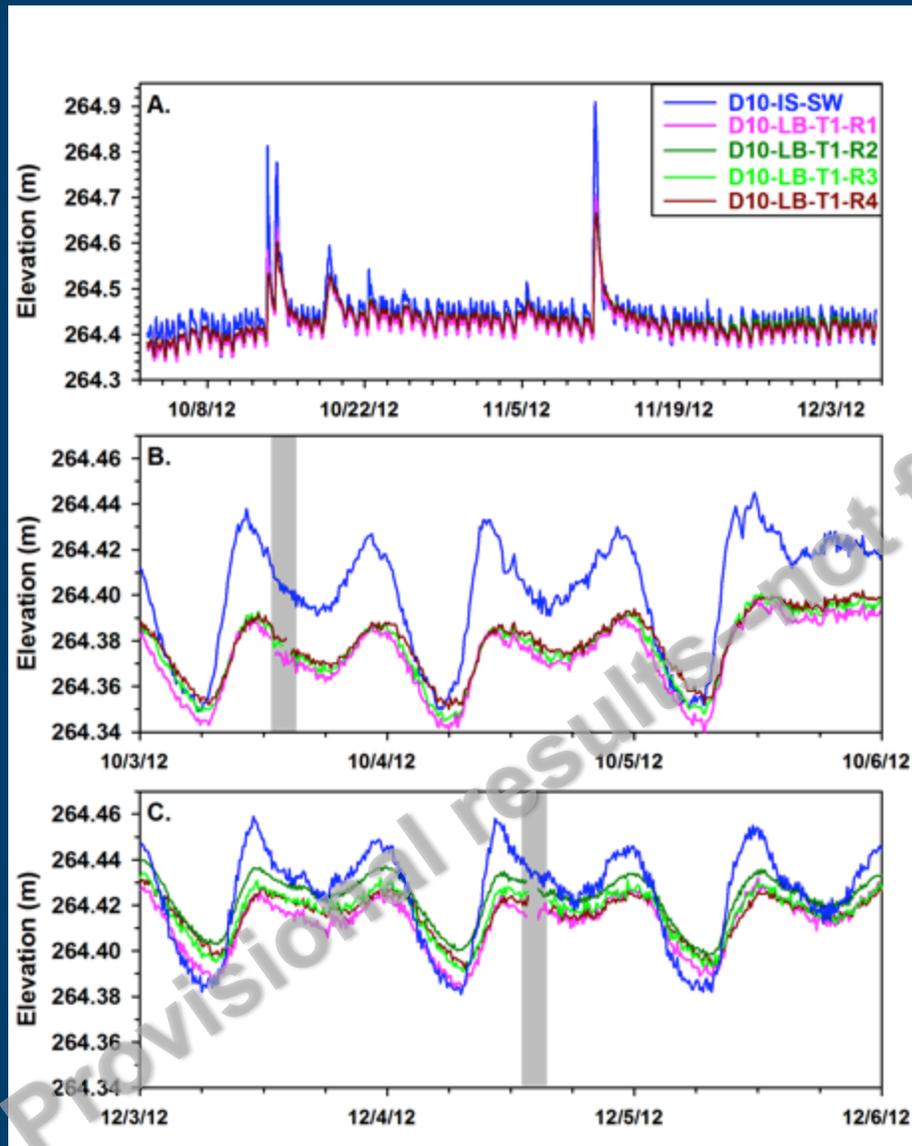


Fourmile Creek: Understanding the Hydrology



Barber et al., 2011

Ankeny WWTP Pre/Post-Closure Assessment: Effluent-Driven Lateral Hydraulic Gradients



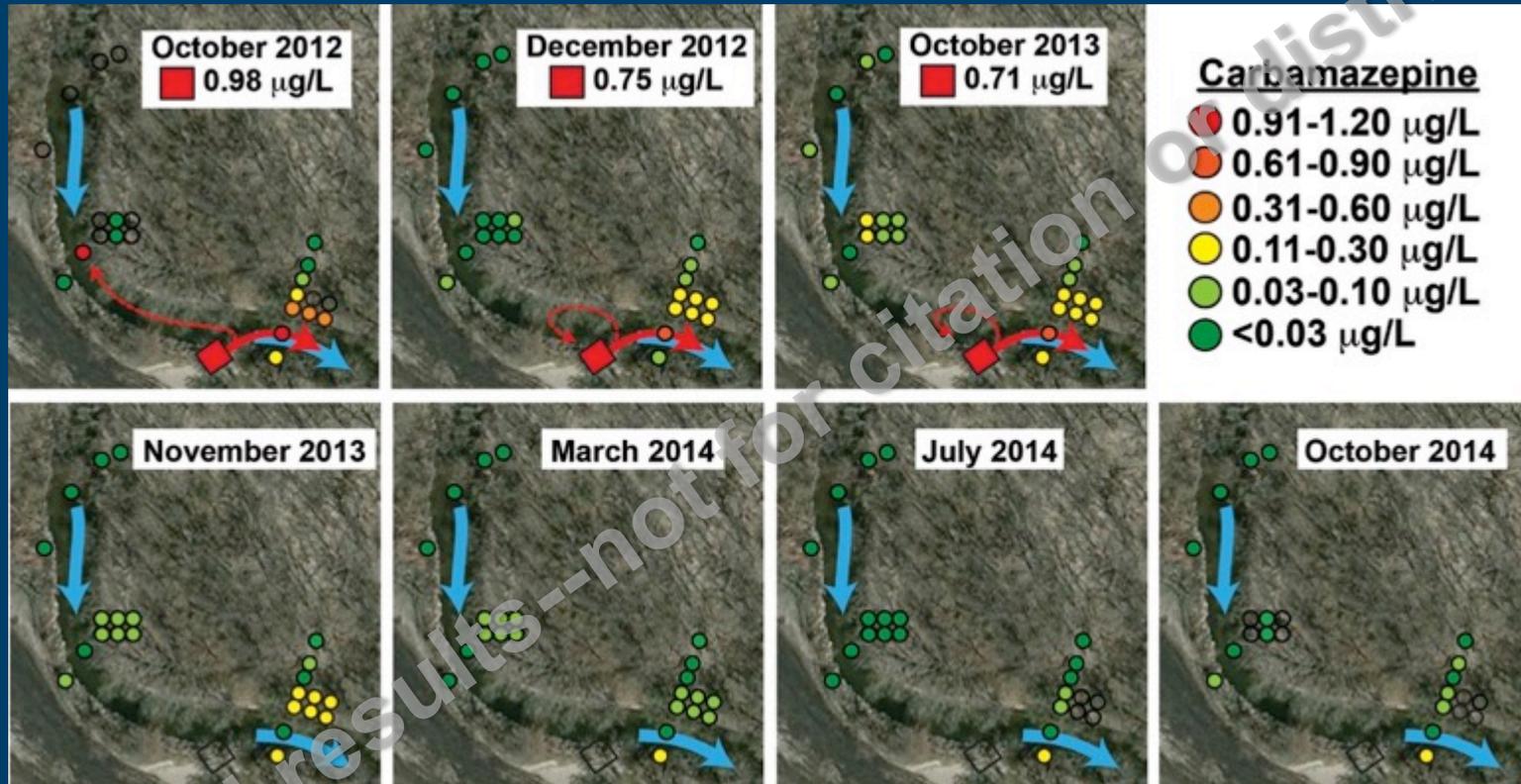
- **October 2012:**
 - **Effluent ~99% downstream flow**
 - **Diurnal pattern (63% dmQ):**
 - Morning & evening peaks
 - Overnight minimum
 - **No gradient reversals**
 - **Effluent drives local GW gradient**
- **December 2012:**
 - **Effluent ~71% downstream flow**
 - **Diurnal pattern (33% dmQ):**
 - Morning & evening peaks
 - Overnight minimum
 - **Gradient reversals**
 - **Effluent drives local GW gradient**
- **November 2013:**
 - **Ankeny WWTP Closed-no discharge**

Ankeny WWTP Pre-Closure Assessment: Lateral & Vertical Gradients



Effluent discharge focused downstream at $\sim 45^\circ$ angle toward opposite bank

Ankeny WWTP Pre/Post-Closure Assessment: Carbamazepine Longitudinal & Lateral Gradient

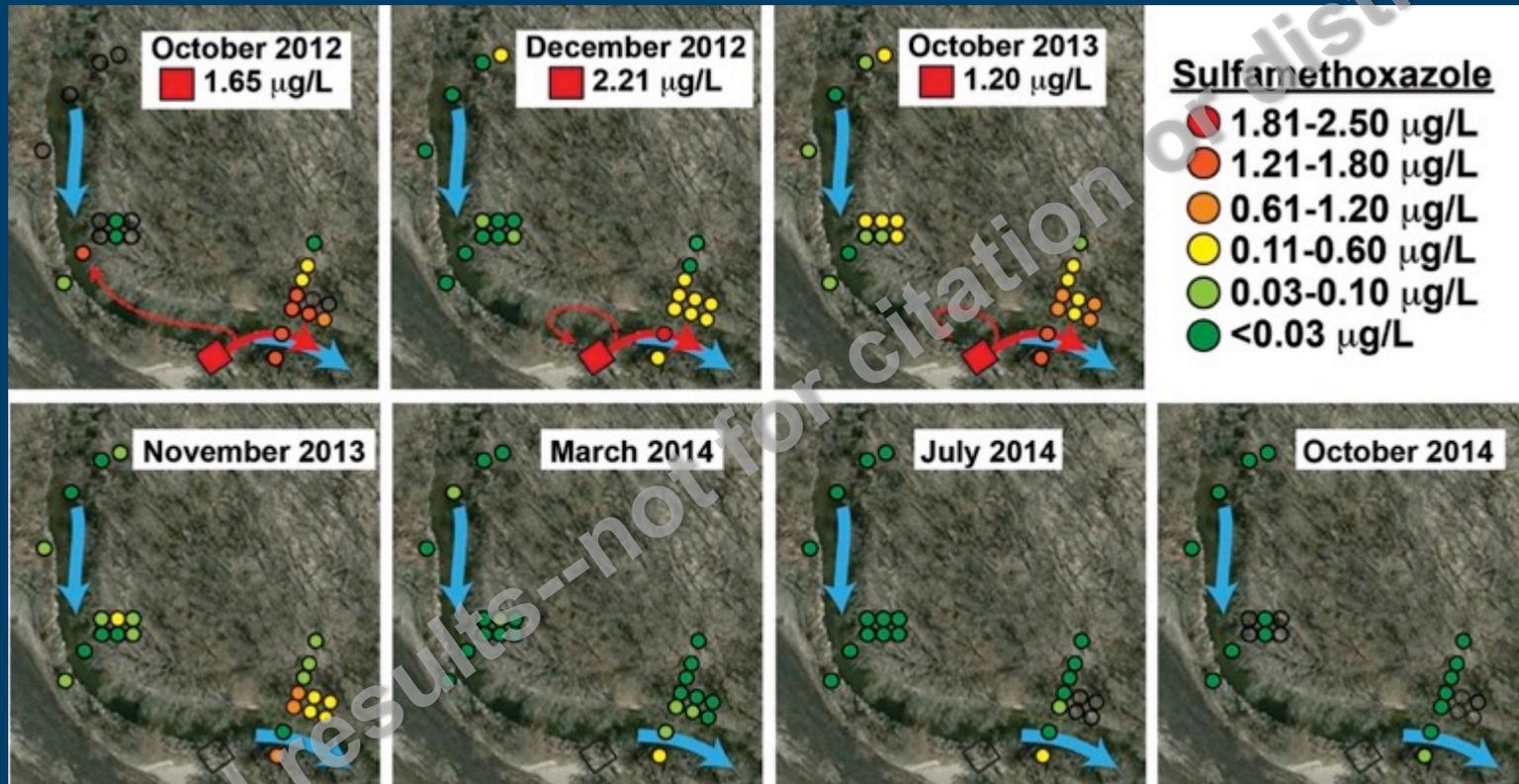


- Effluent source--Eddy recirculation--Lateral infiltration



Bradley et al., 2014; Bradley et al. (submitted)

Ankeny WWTP Pre/Post-Closure Assessment: Sulfamethoxazole Longitudinal & Lateral Gradient



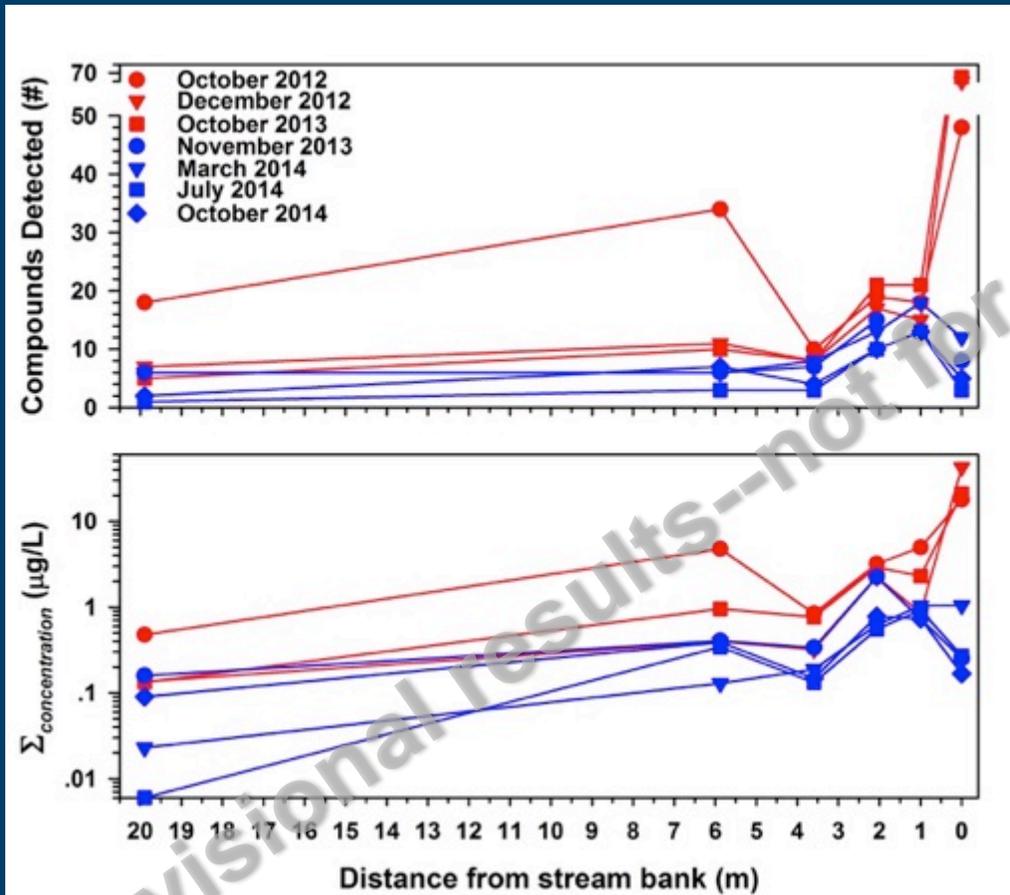
- Effluent source--Eddy recirculation--Lateral infiltration



Bradley et al., 2014; Bradley et al. (submitted)

Ankeny WWTP Pre-Closure Assessment: 109 Pharmaceuticals Lateral Gradient

- ~ 60% Attenuation (1 m)
- 7-18 Pharms @ 20m:
 - \sum_{conc}
 - October = 476 ng L⁻¹
 - December = 136 ng L⁻¹



Analytes:

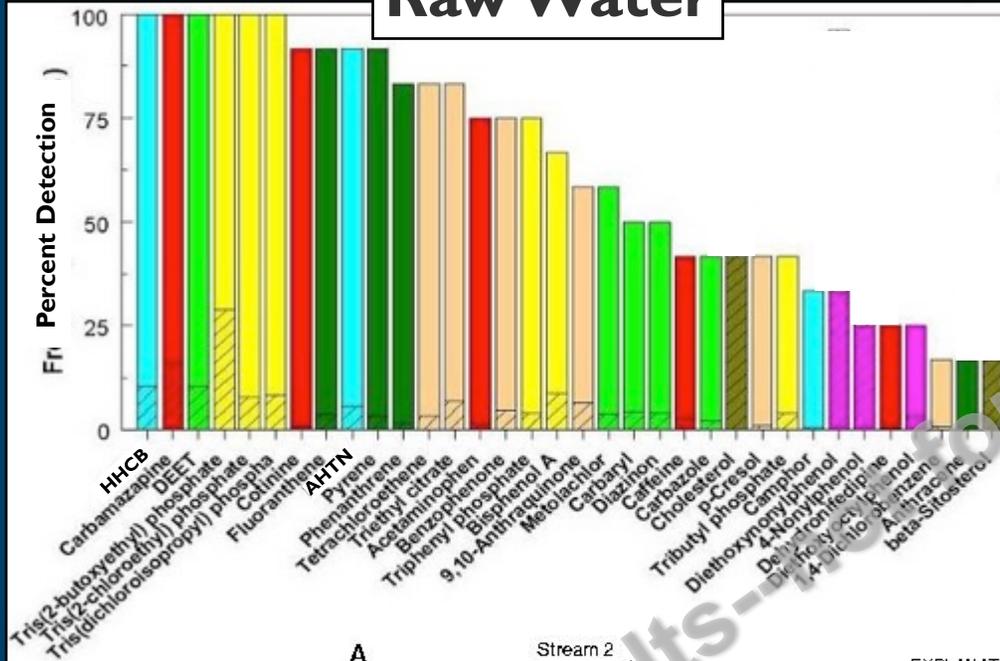
- Acyclovir – anti-viral
- Bupropion – anti-depressant
- Caffeine – natural stimulant
- Carbamazepine – anti-convulsant
- Carisoprodol – muscle relaxant
- Desvenlafaxine – anti-depressant
- Fexofenadine – anti-histamine
- Lidocaine – anesthetic
- Metformin – anti-diabetic
- Meprobamate – anti-anxiety
- Methocarbamol – muscle relaxant
- Methotrexate – cancer
- Metoprolol – blood pressure
- Nicotine – natural stimulant
- Sulfamethoxazole – antibiotic
- Temazepam – insomnia
- Tramadol – analgesic
- Warfarin – blood thinner

USGS

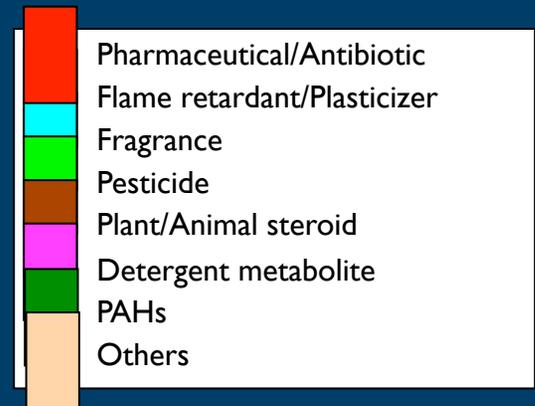
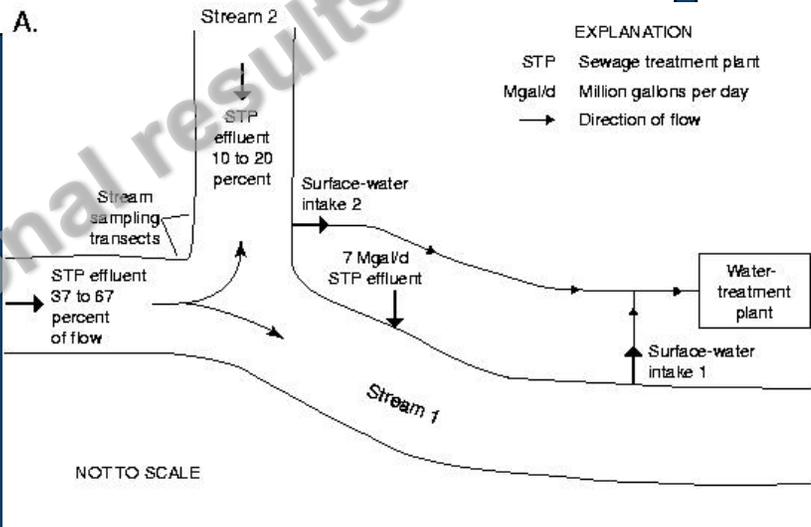
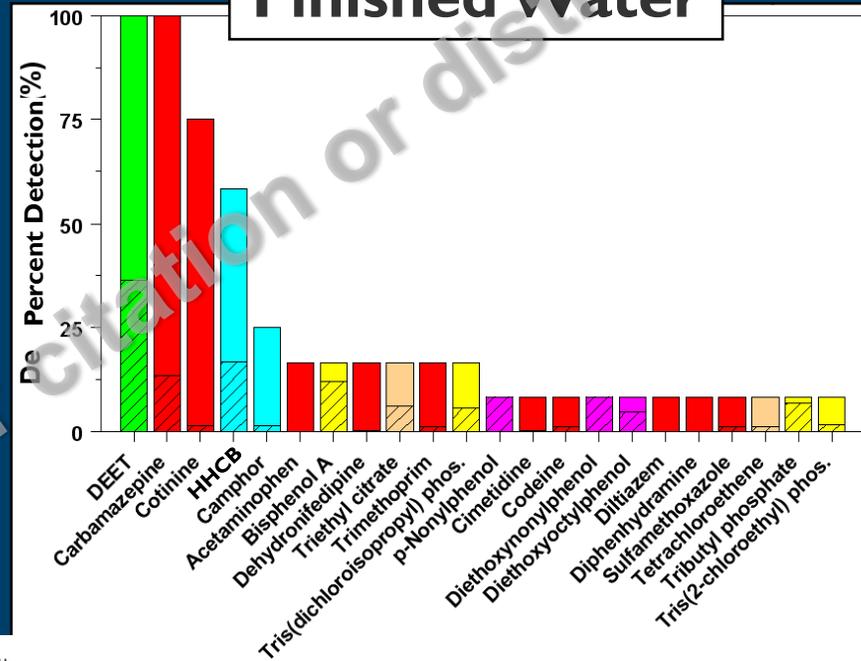
Bradley et al., 2014; Bradley et al. (submitted)

Removal in Treatment, NJ Facility

Raw Water



Finished Water



Stackelberg et al., 2004 & 2007

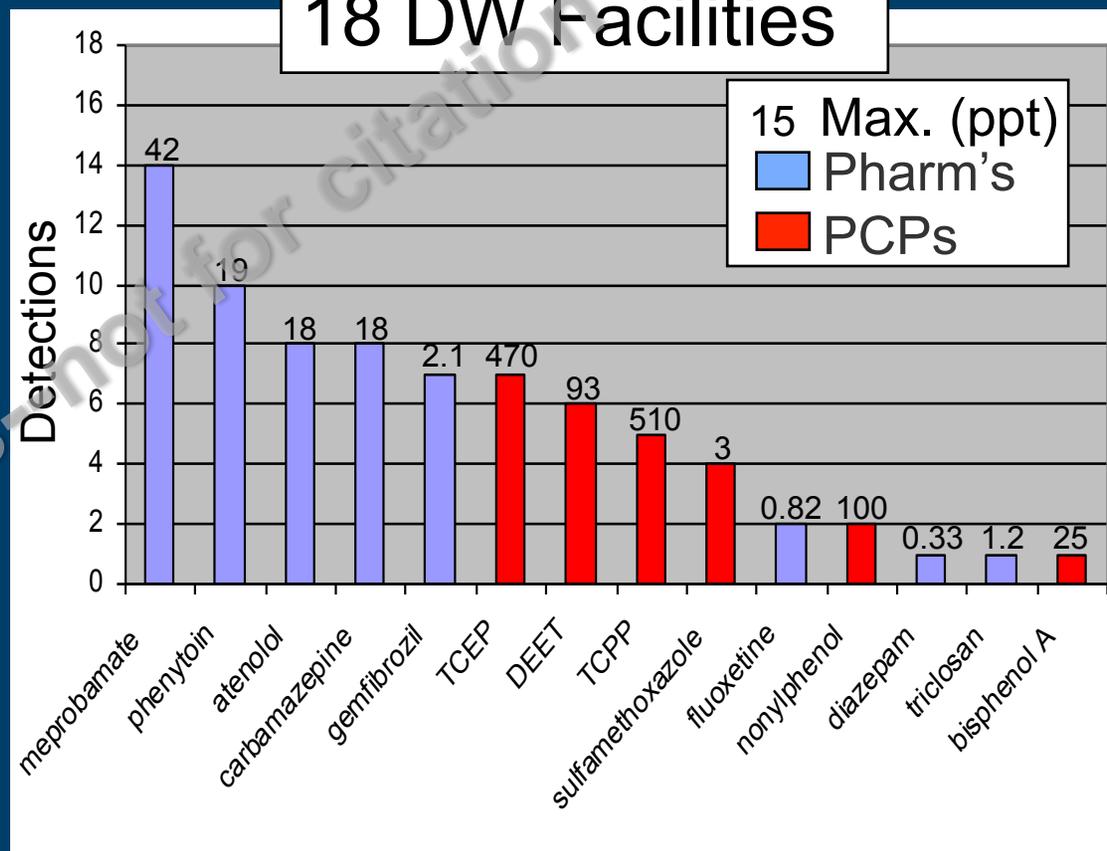
CECs in Finished Drinking Water

Conducted by
Southern Nevada
Water Authority

Supported by AWWA
Research Fnd. &
WaterReuse Fnd.



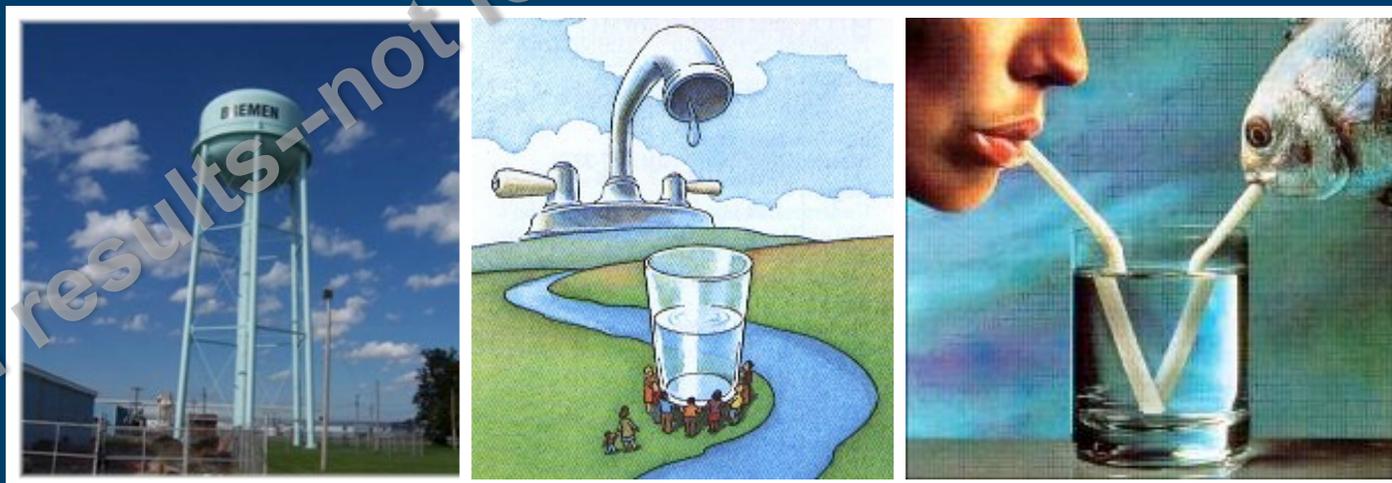
18 DW Facilities



Benotti et al. 2008



Pharmaceuticals and Other Contaminants of Emerging Concern in Source and Treated Drinking Water—Results from a national study.



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

USGS-USEPA Interagency Project Collaborators, Contributors, and Co-Authors

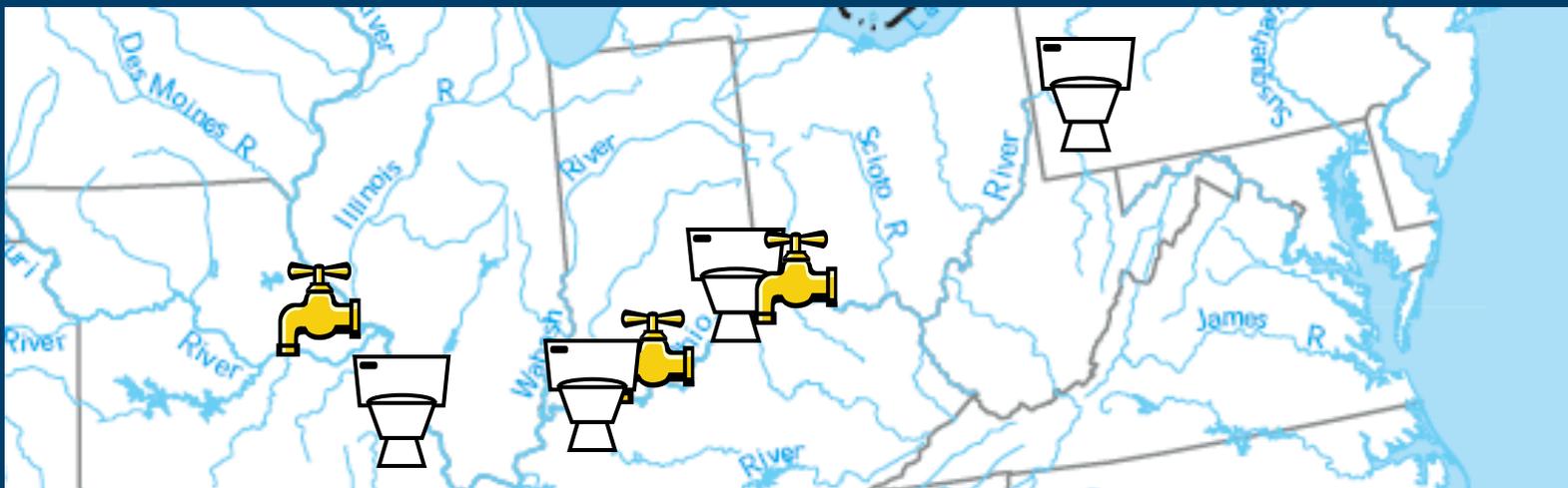
- Susan Glassmeyer
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- Vickie Wilson



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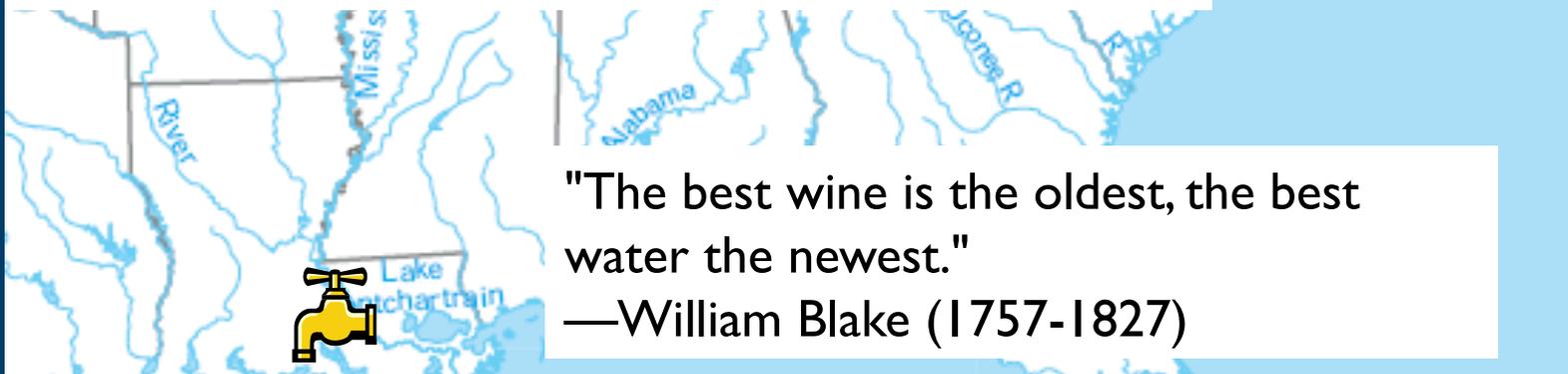
- *The participating drinking water treatment plants!*
- *NWQL Scientists: Mary Noriega, Laura Coffey (AS), Chris Kanagy (MRDP)*
- *Funded through IA DWI 4922330*
- *Additional project support from the USGS Toxic Substances Hydrology Program*





1980 USEPA survey found 20 communities (>7 million people) with drinking water source water containing 2.3-16% wastewater during average flow

(EPA-600/2-80-044)



"The best wine is the oldest, the best water the newest."

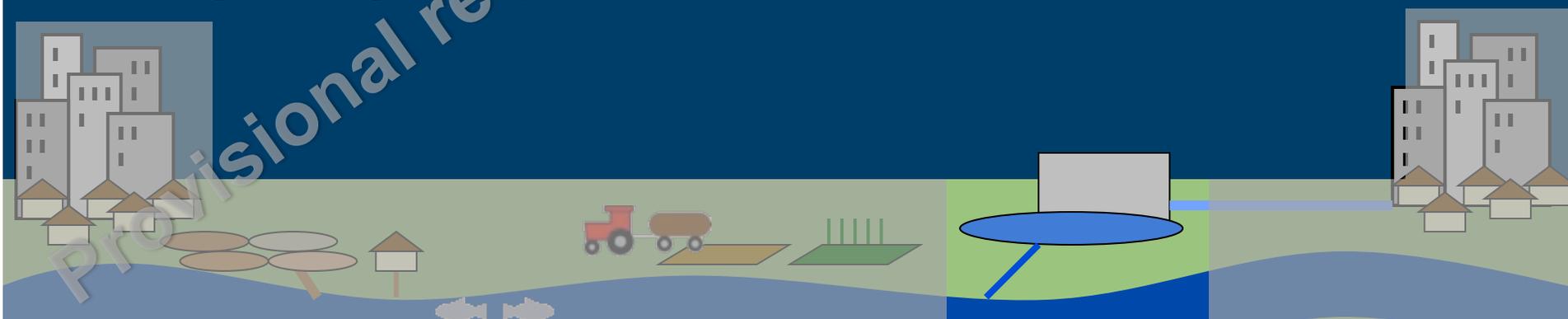
—William Blake (1757-1827)



CECs in Untreated and Treated Drinking Water

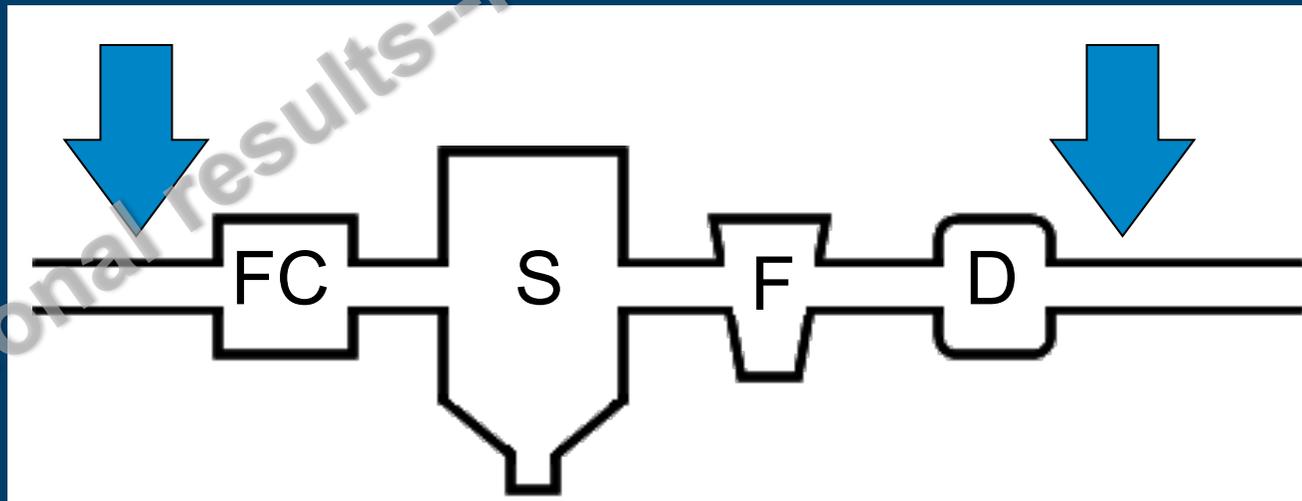


- Multiyear Project (Interagency Agreement) between USGS and USEPA
- Source and treated drinking water pairs from 25 locations
- 247 chemical and microbial analytes
- Duplicate, laboratory fortified matrix (spike) and field blank collected at each location
 - ~ 70% of analyses were QA/QC samples
- Bioassay for estrogenic activity
- Human health margin of exposure assessment
- Ecological margin of exposure assessment



Project Sampling Design:

- Paired untreated and treated water samples, collected taking the residence time of the plant into account.
- Locations sampled only once.
- 249+ chemical analytes.
- All samples preserved with ascorbic acid.
- QC Samples:
 - A primary sample, replicate sample, and matrix spike sample collected for each untreated and treated water
 - A field blank collected for each DWTP

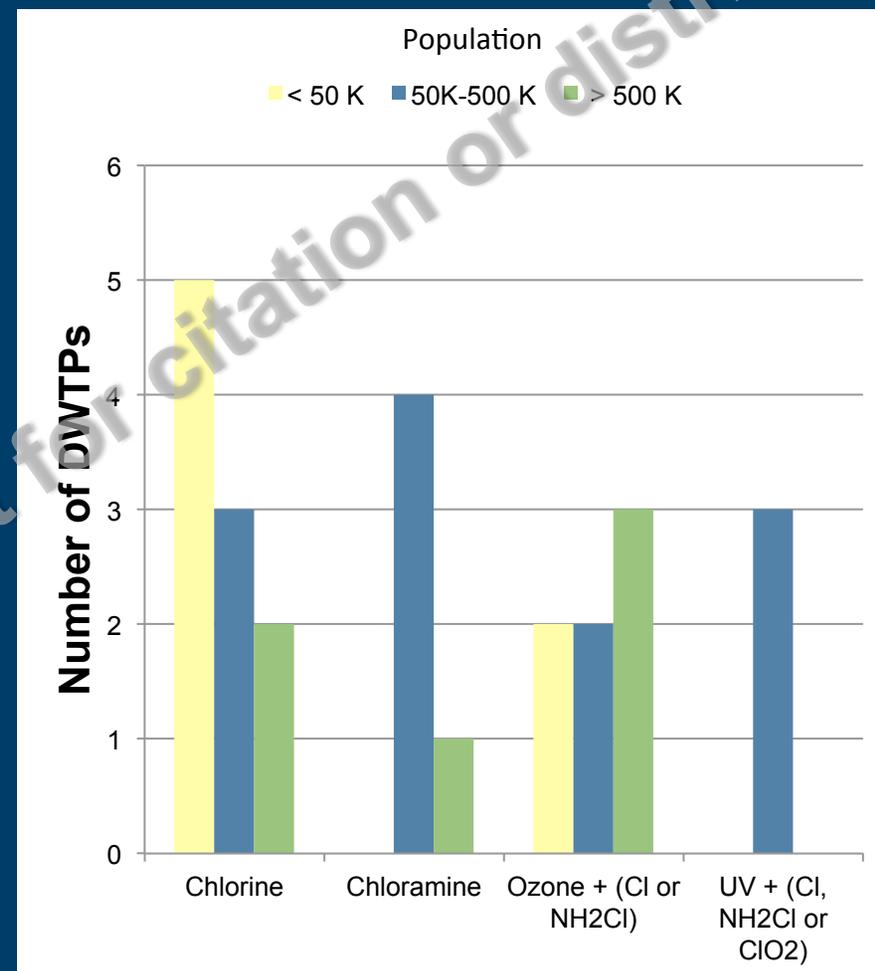
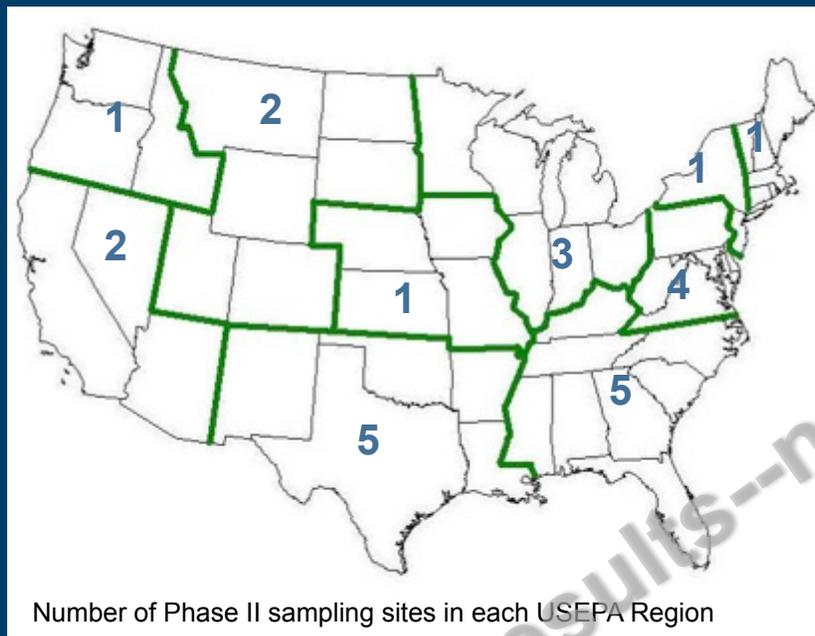


QA/QC Samples- Organic Chemical Analyses

- Every location had 7-8 samples collected:
 - Primary sample for both source and treated samples
 - Duplicate sample for both source and treated samples
 - Laboratory Fortified Matrix (LFM aka matrix spike) for both source and treated samples
 - Field Blank- 1 or 2 depending on method
- Laboratory Blank- every batch of 6-10 samples
- Laboratory Fortified Blank (LFB aka lab spike)- every batch of 6-10 samples
- Lowest Concentration Minimum Reporting Level (LCMRL)



Location Information



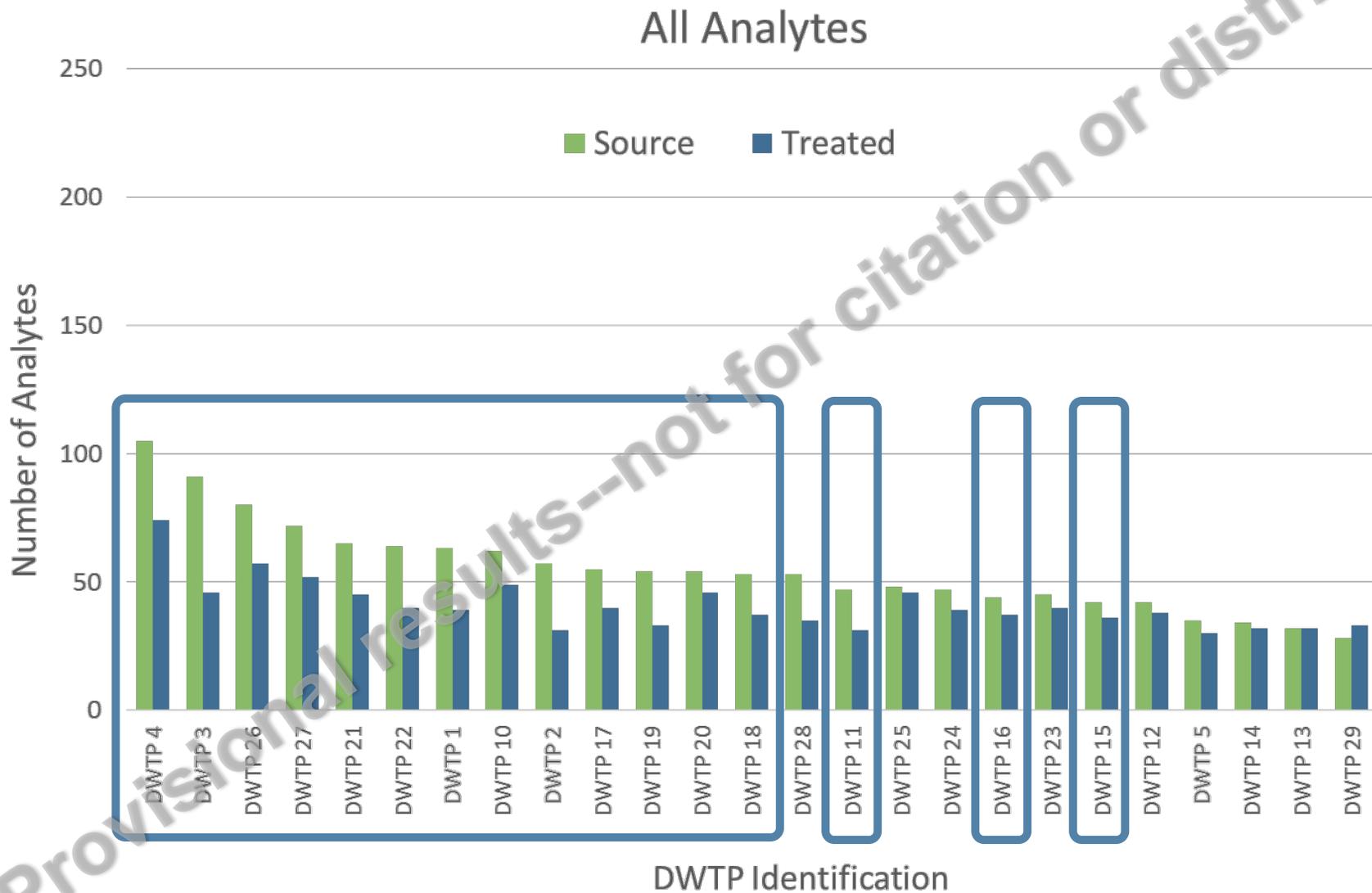
QA/QC Impacts to Organic Chemical Data

Performance Measure	Action	Number of Affected Measurements	
		Source	Treated
Concentration less than LCMRL or RL	Qualitative detection	299	159
Non-quantifiable detection	Qualitative detection	9	7
Matrix spike associated with sample > 150% recovery	Qualitative detection	71	41
Sample concentration does not exceed 3 × field and/or laboratory blank concentration	Detection censored	244	290
Median recovery < 50% for the LFB, Source LFM and/or Treated LFM	Analyte censored (48 analytes)	15	6
LFB, Source LFM and/or Treated LFM Failure Frequency > 40%	Analyte censored	0	0
RSD between all LFB, Source LFM or Treated LFM > 50%	None	0	0



Qualified or censored detections	638	503
Quantified Organic Chemicals	416	294

Qualitative Frequency of Detection



Commonly Detected in Source Water

Pharmaceuticals

sulfamethoxazole
lithium
carbamazepine
metoprolol
estrone
aciclovir
metformin
methocarbamol
meprobamate
caffeine
tramadol

PFCs

PFOA
PFBS
PFOS
PFHxA
PFHpA
PFNA
PFBA
PFPeA
PFHxS
PFDA
PFUnDA

AWIs

triclocarban
triclosan
benzotriazole
methyl-1H
DEET
atrazine
metolachlor
galaxolide
tri(2-butoxyethyl)
phosphate
tri(2-chloroethyl)
phosphate

Inorganics

strontium
barium
calcium
sodium
sulfur
magnesium
silicon
potassium
total dissolved
nitrogen
fluoride
nitrate
aluminum
zinc
sulfate
chloride
iron
manganese
phosphorus
copper
phosphate
bromide
lead
uranium
ammonia
arsenic
nitrite
nickel
vanadium
tin

Microorganisms

Aspergillus fumigatus
Giardia
Adenovirus
Aspergillus terreus

Commonly Detected in Treated Water

Pharmaceuticals

lithium
metoprolol

PFCs

PFOA
PFBS
PFHxA
PFPeA
PFOS
PFHpA
PFNA
PFBA
PFHxS
PFDA
PFUnDA

AWIs

bromoform
triclosan
benzotriazole
methyl-1H
isophorone
atrazine
metolachlor
tri(2-chloroethyl)
phosphate

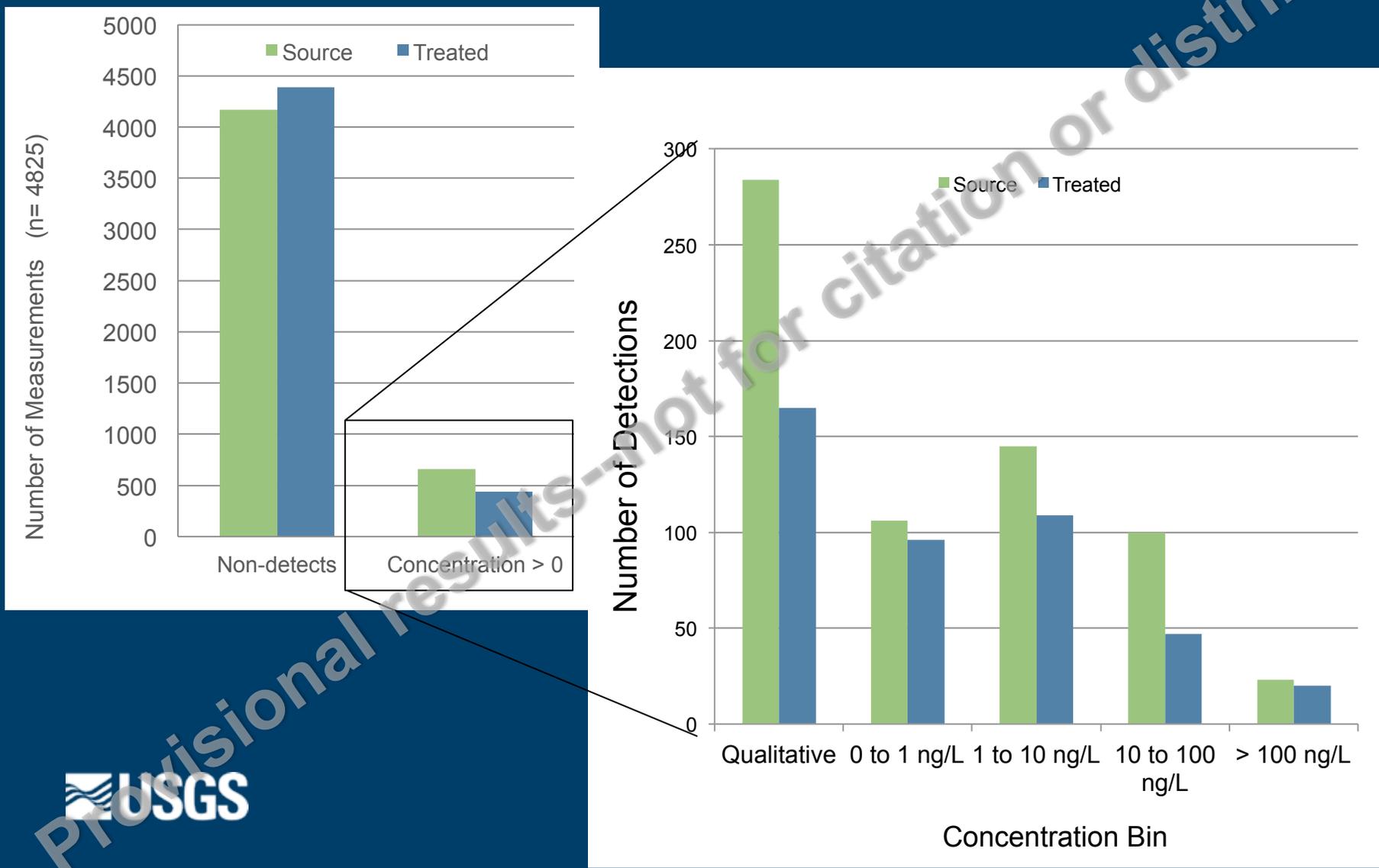
Inorganics

strontium
barium
calcium
sodium
sulfur
magnesium
silicon
potassium
total dissolved
nitrogen
fluoride
nitrate
aluminum
zinc
sulfate
chloride
iron
manganese

Microorganisms

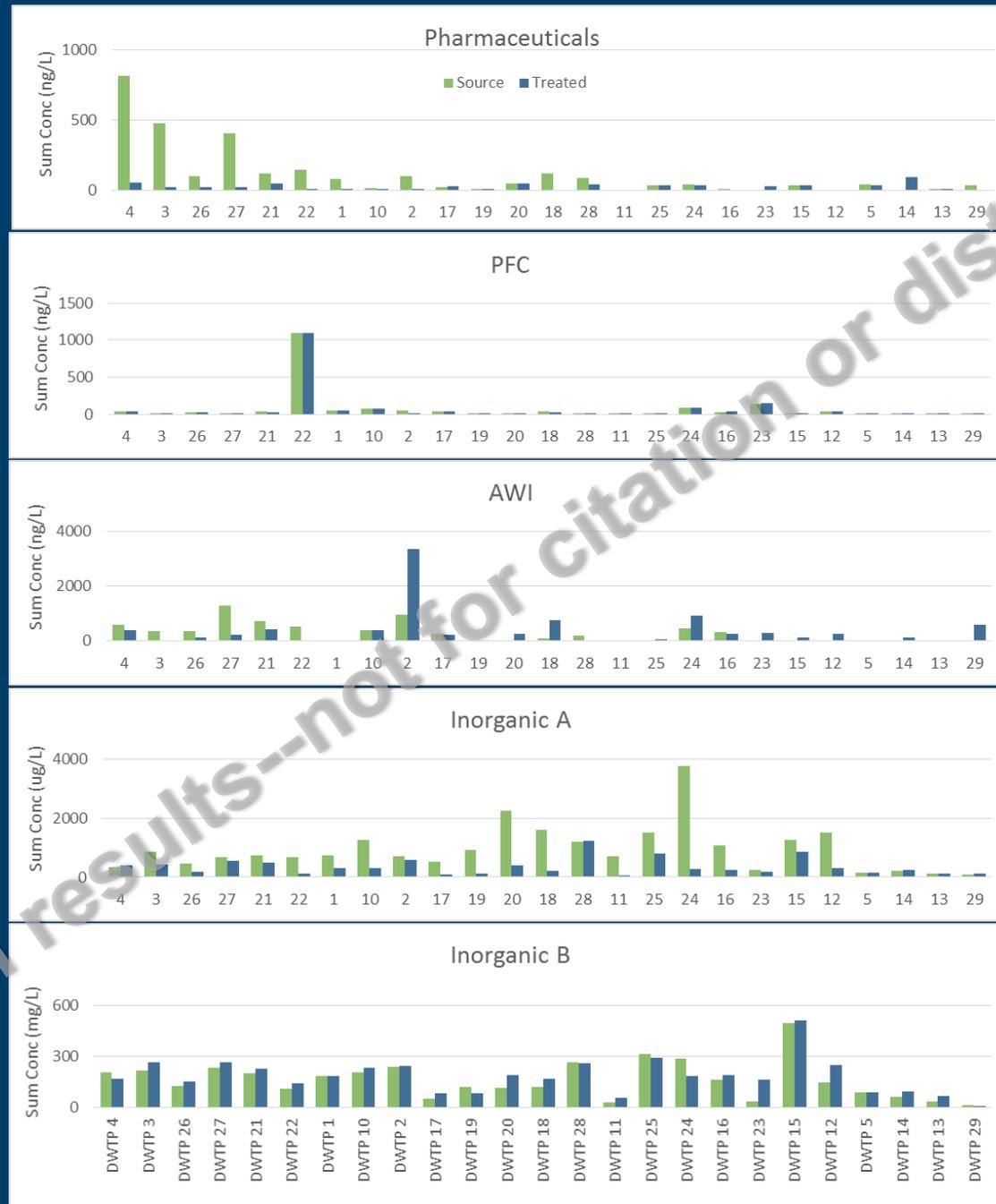
phosphorus
copper
phosphate
bromide
chlorate
uranium
ammonia
arsenic
selenium
nickel
tin

Organic Chemical Concentration Bins



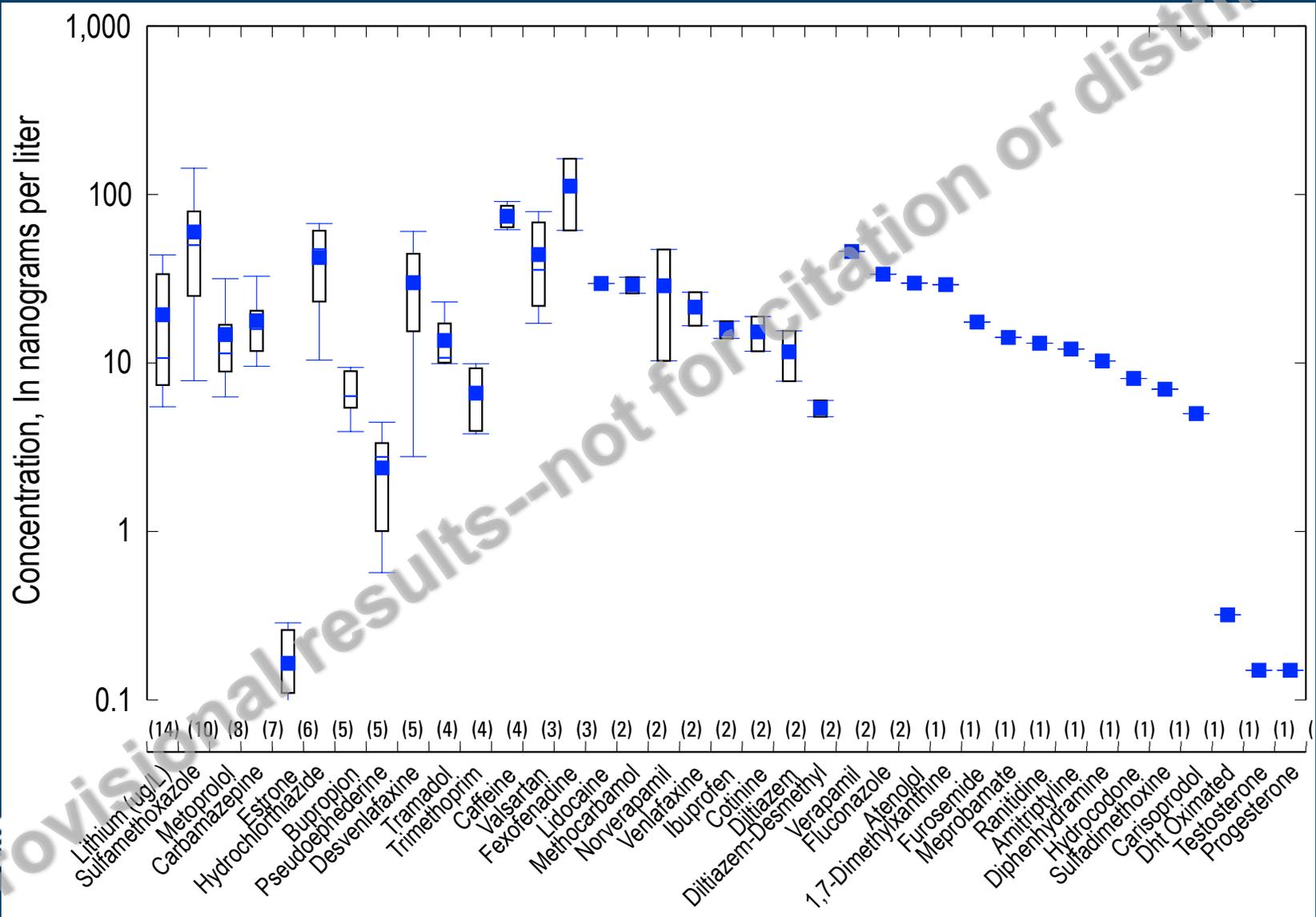
Provisional results - not for citation or distribution

Summed Conc. by Analyte Class

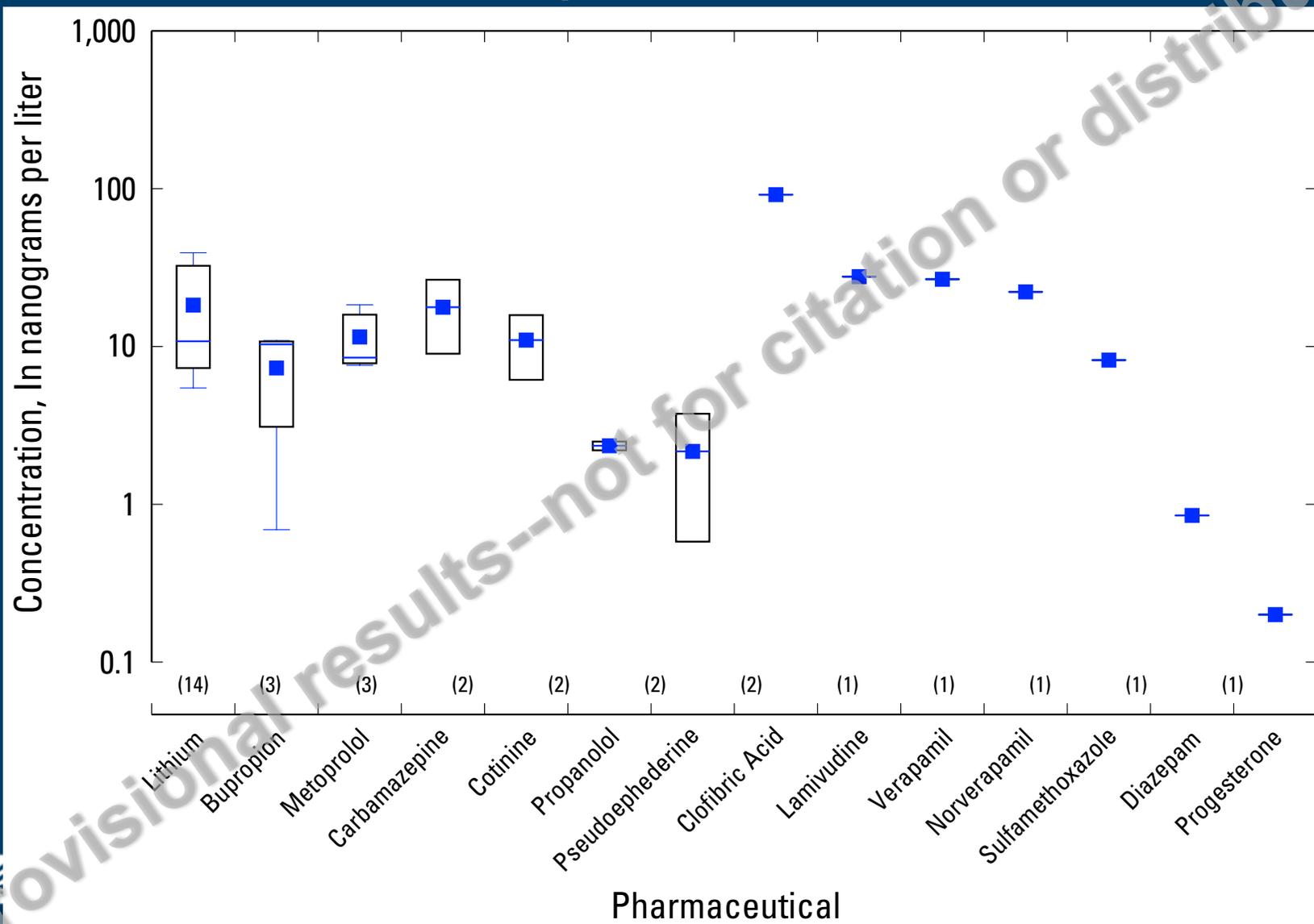


Provisional results--not for citation or distribution

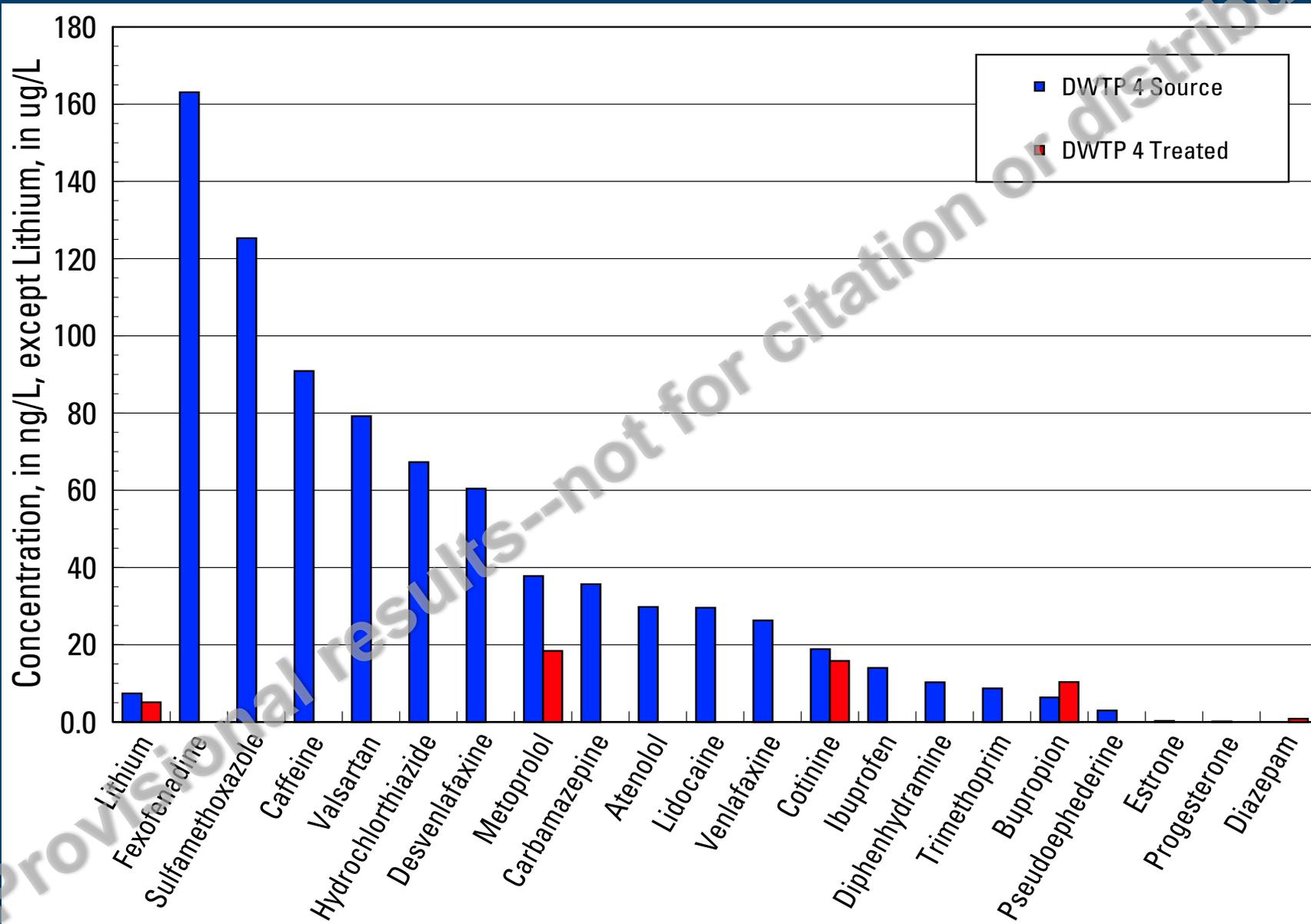
Most Frequently Detected Pharmaceuticals: Source Water Samples



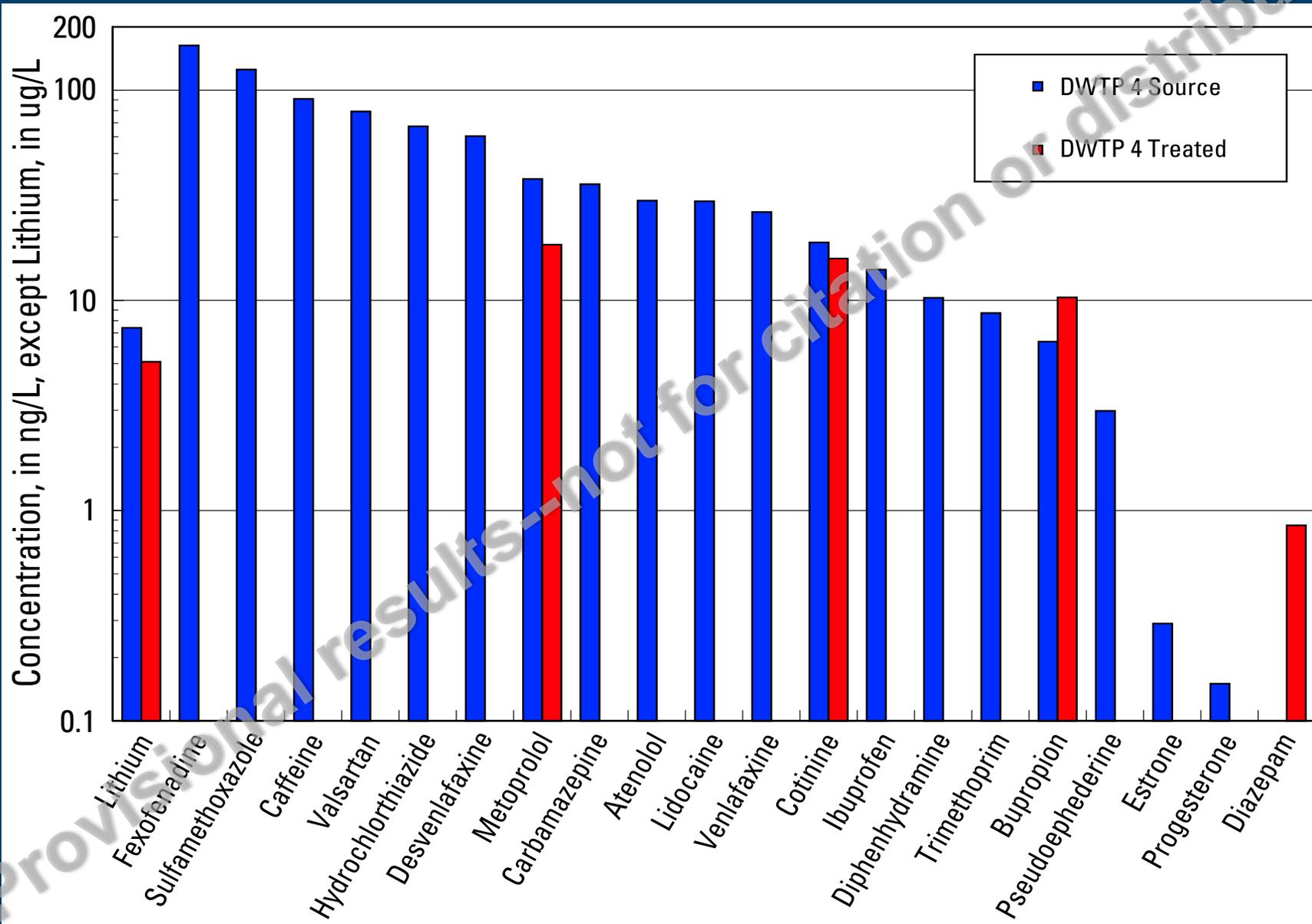
Most Frequently Detected Pharmaceuticals: Treated Water Samples



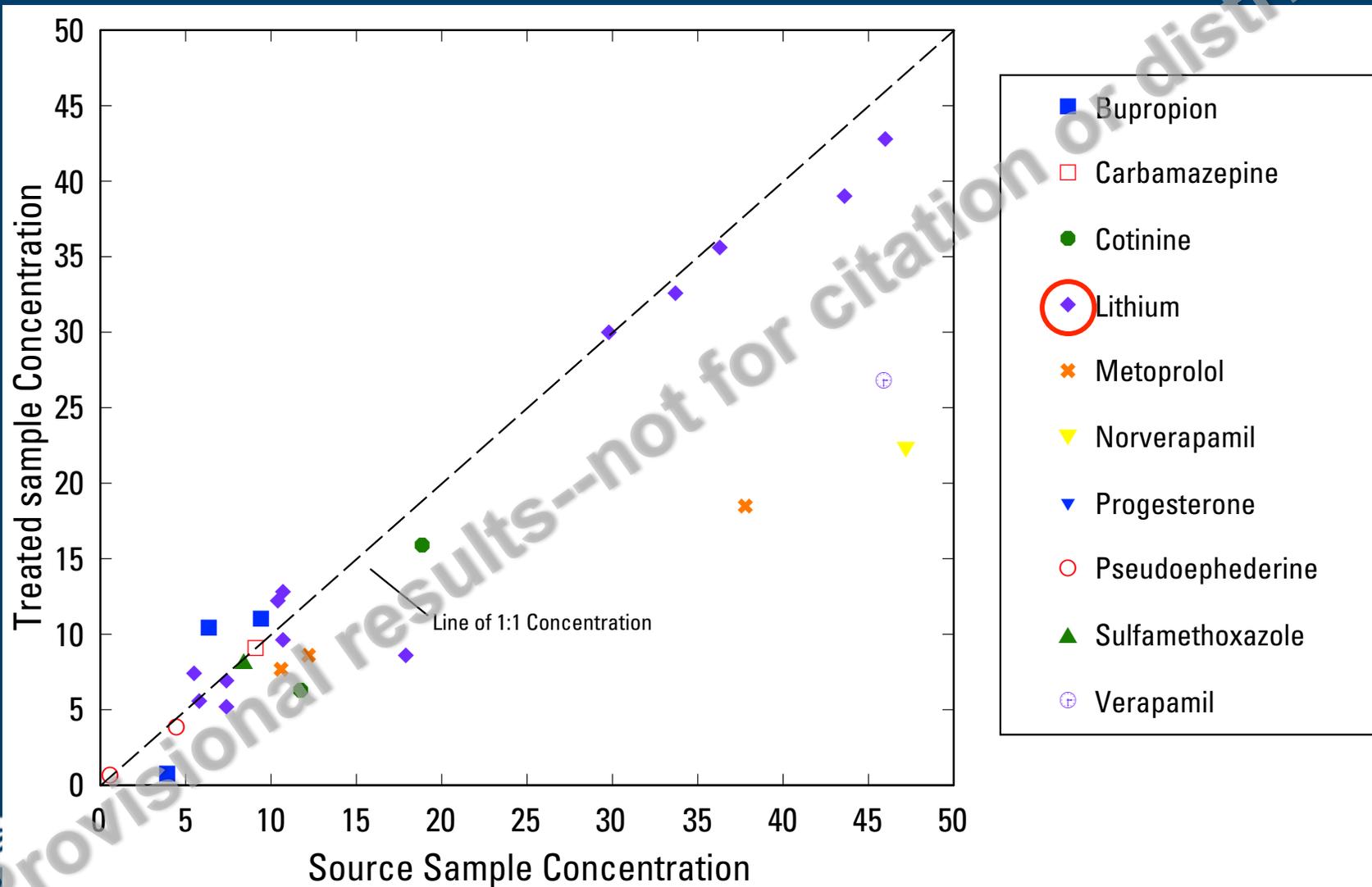
Source vs. Treated Water— Pharmaceuticals :



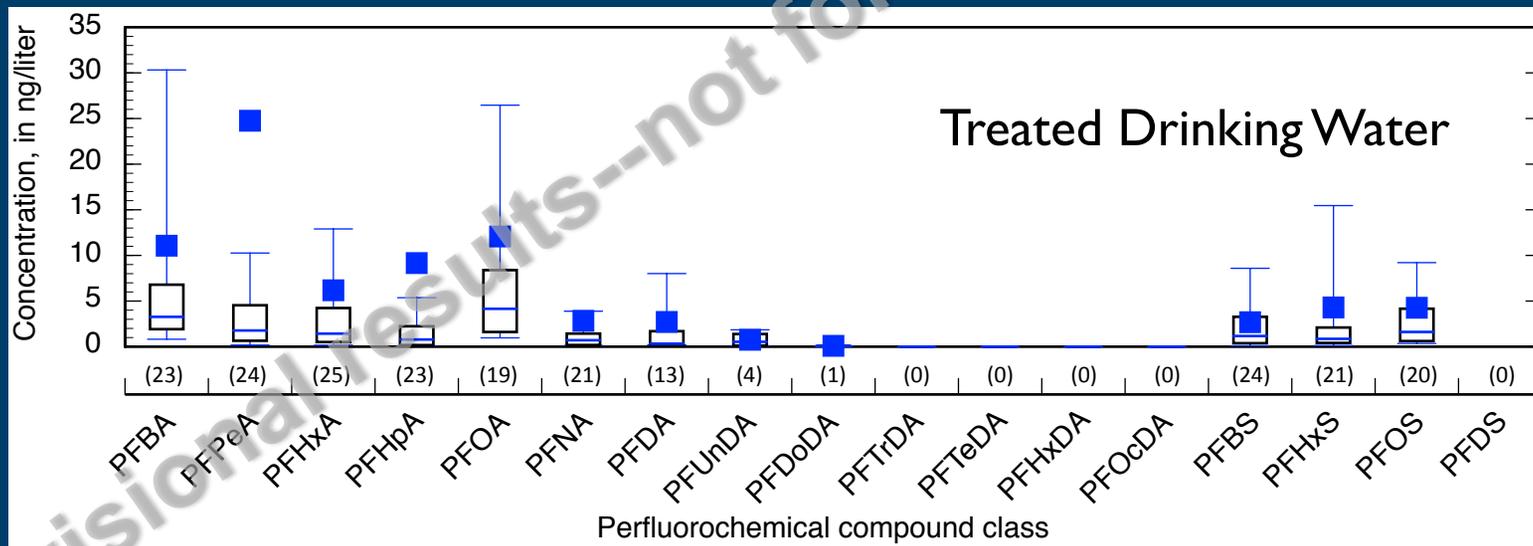
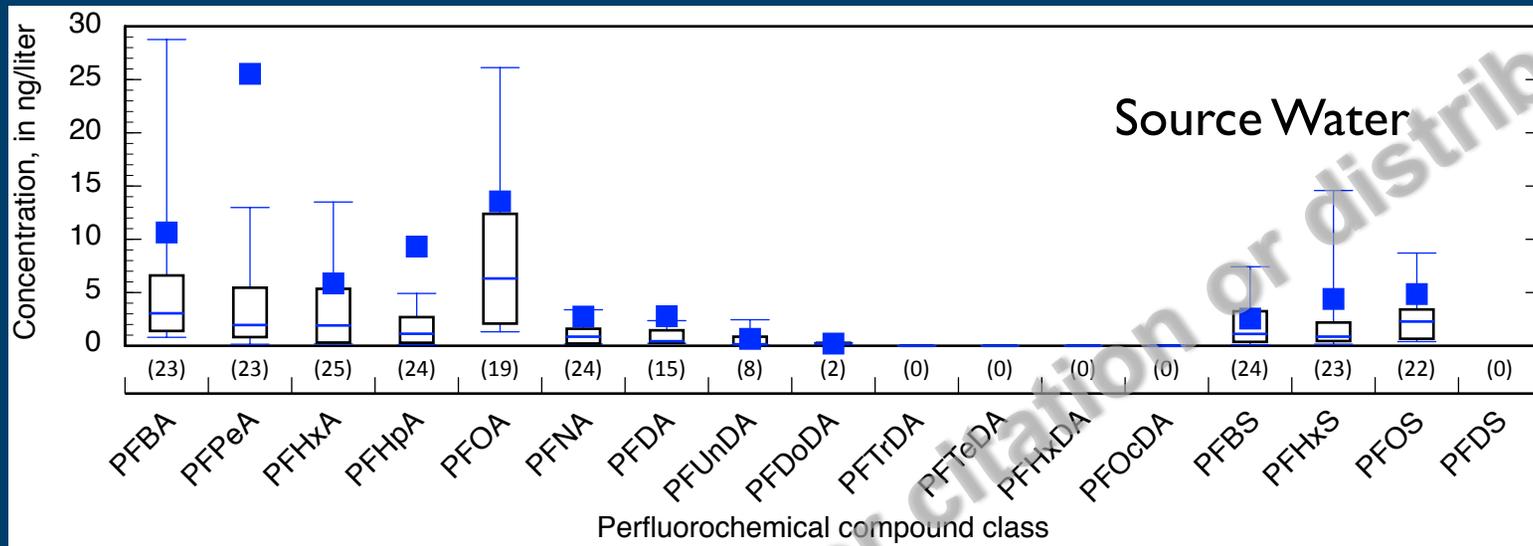
Source vs. Treated Water— Pharmaceuticals:



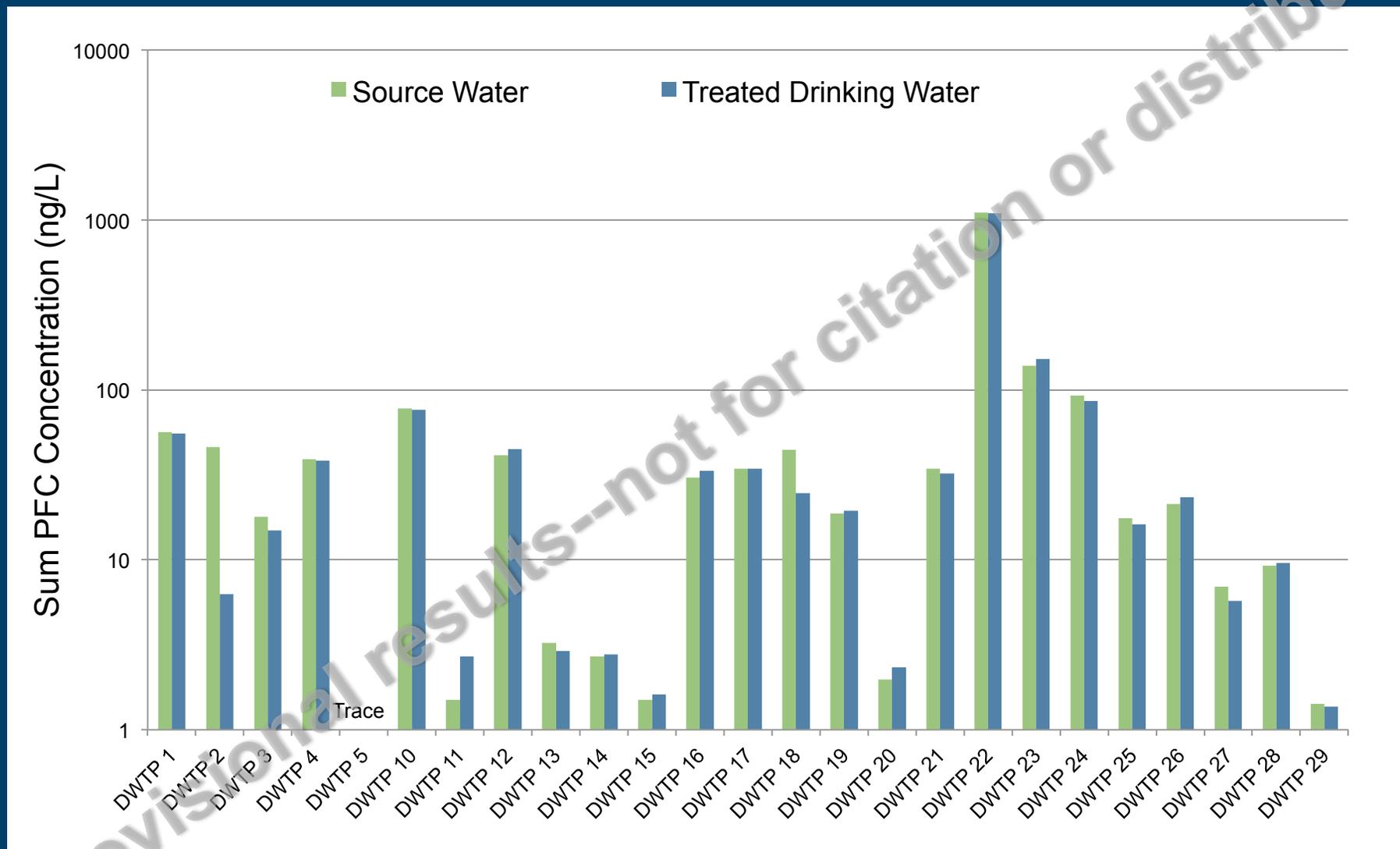
Comparison between Source and Treated Samples:



PFCs: Concentration Ranges by Homologue



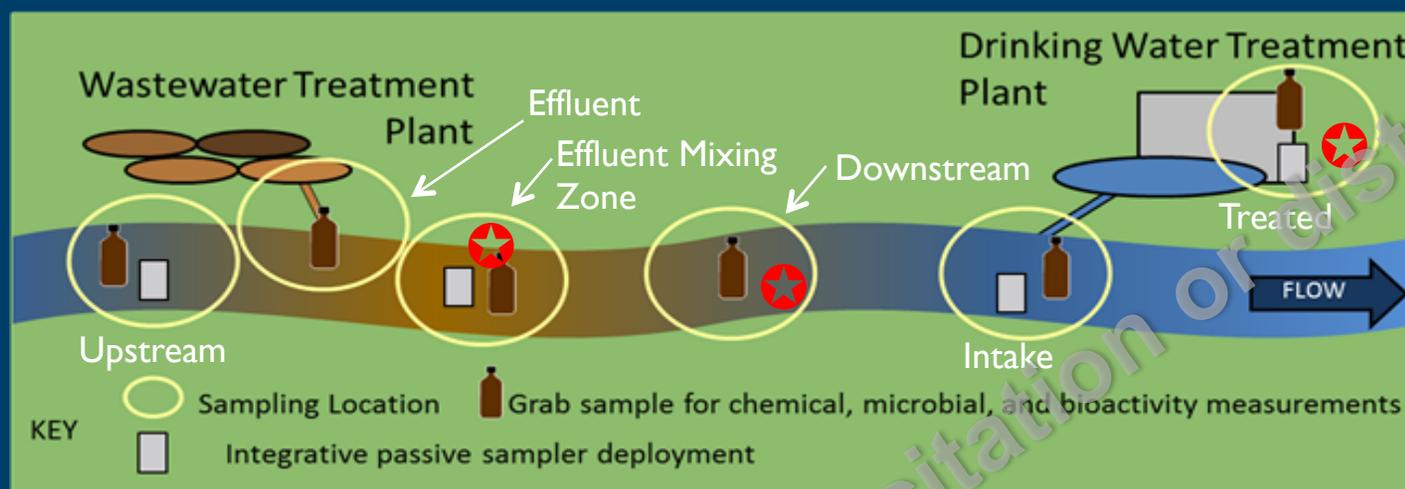
PFC Concentration Trends



Take Home Messages

- Of the 247 analytes measured, 98 were never detected in the source water samples; 123 were never detected in the treated drinking water samples.
- The frequency of detection of pharmaceuticals in the source water seems to be more strongly linked to the type of water (river, lake/reservoir or ground water) than PFCs, inorganic analytes or microorganisms.
- Concentrations of detected organic chemicals were <10 ng/L.
- Concentrations of analytes was more variable between locations than frequency of detection, especially for the PFCs and inorganics
- More research is needed on the toxicity associated with environmentally relevant concentrations of CECs.

Wastewater to Drinking Water Project (WW2DW)



- **Goal:** examine the occurrence, fate, and transport of CECs as they travel from WWTP into DWTP.
- **Sampling plan:** collect residence-time weighted (Lagrangian) samples to analyze for chemicals, microorganisms, and bioactivity.
 - One location
 - Three sampling events (**Oct 2014, April 2015, and Aug 2015**)
 - Six sampling points
 - **Extensive QC:** Primary, Replicate, Matrix Spike samples collected at each site each time. Three field blank samples per trip (indicated by ☆)

WW2DW

Chemical Analytes ~200

- Pharmaceuticals
- Hormones
- Alkylphenols
- PFCs
- Sucralose
- DBPs
- 1,4-Dioxane
- Metals and inorganics
- Unknown Analysis

Bioassays:

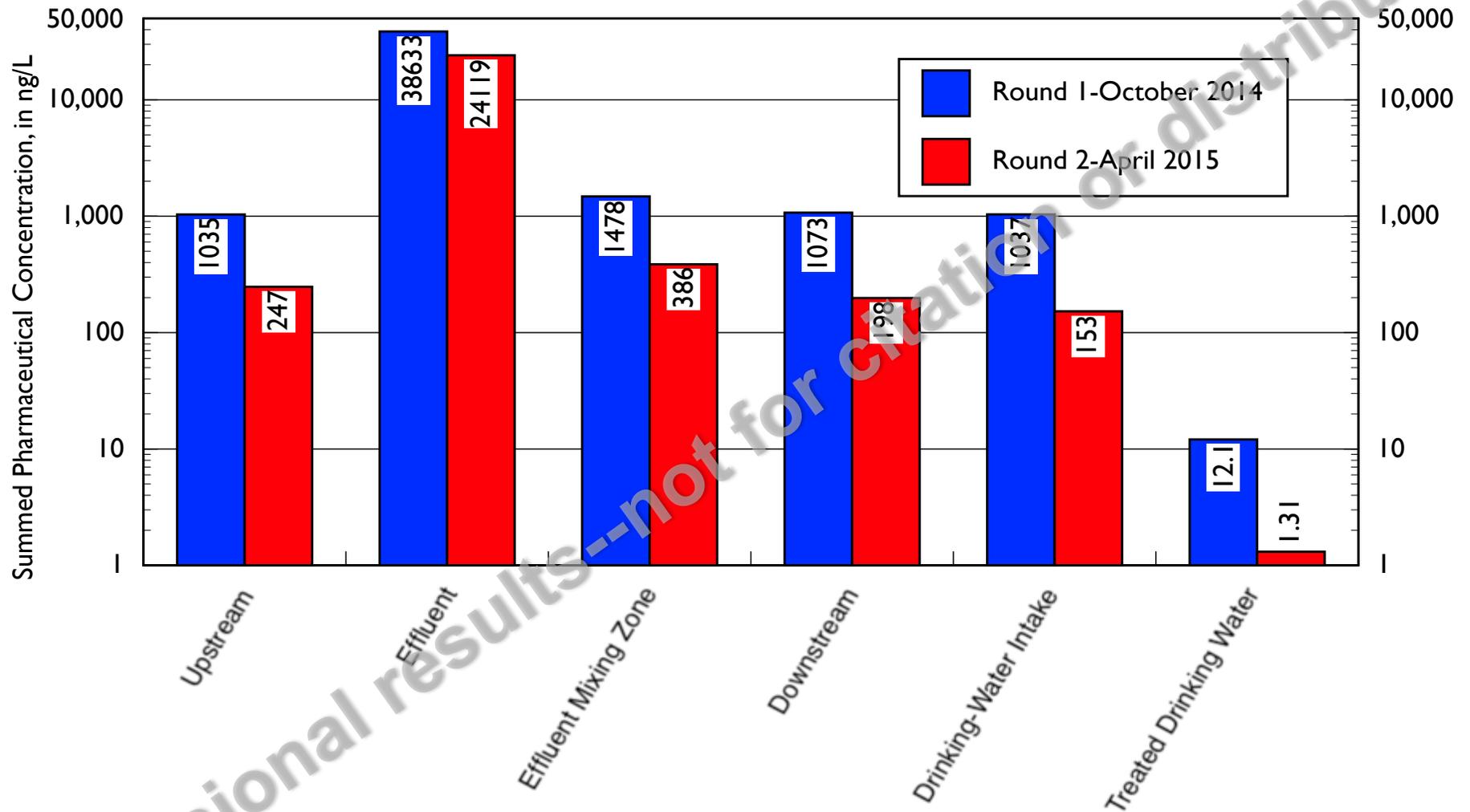
- Estrogens
- Androgens
- Glucocorticoids
- Genotoxic Chemicals
- Liver Cell Toxicology
- Colonocyte Assays
- Steriodogenesis
- Gene Expression
- Metabolite Profiling



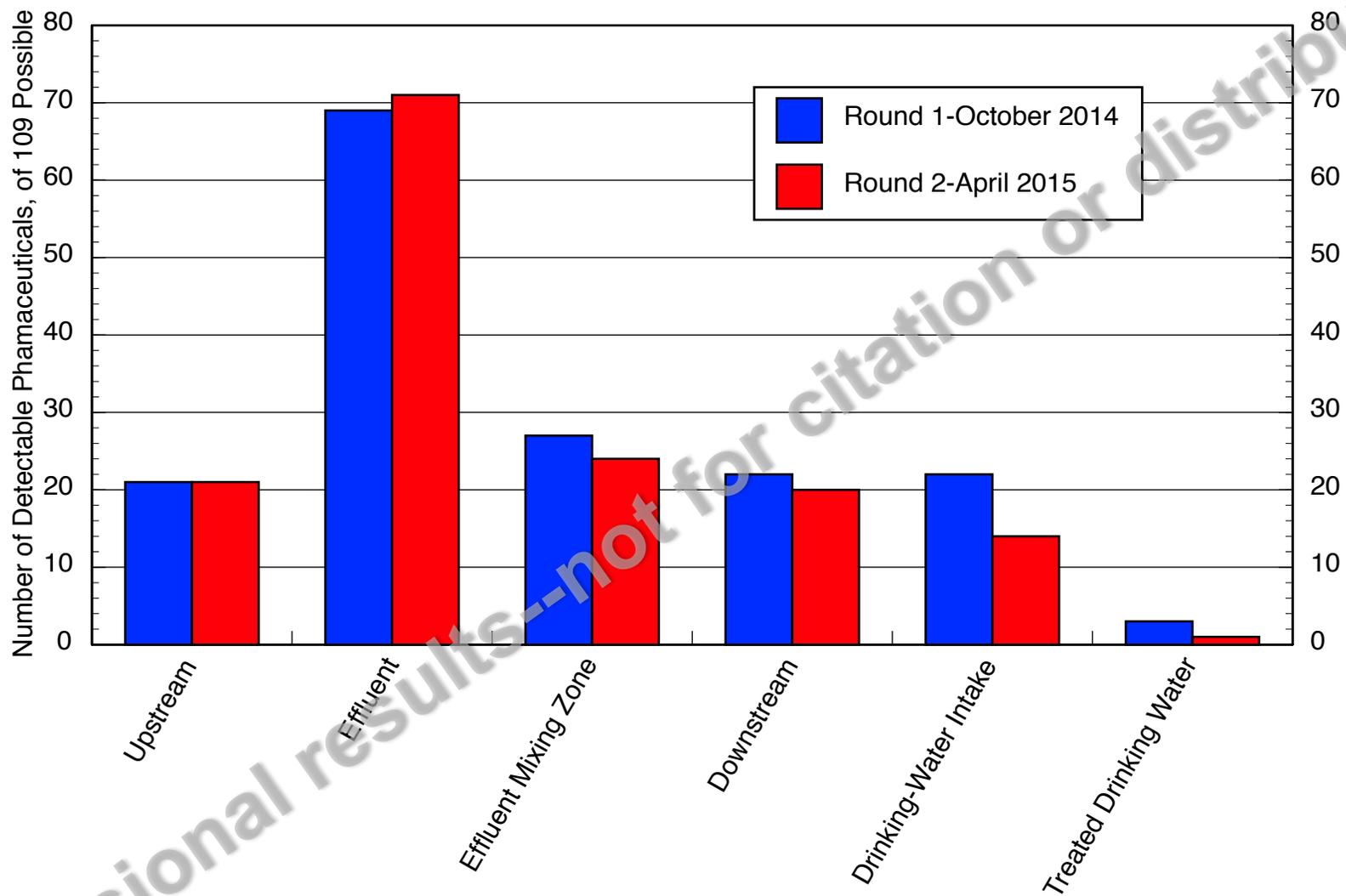
And Microorganisms, too!!!

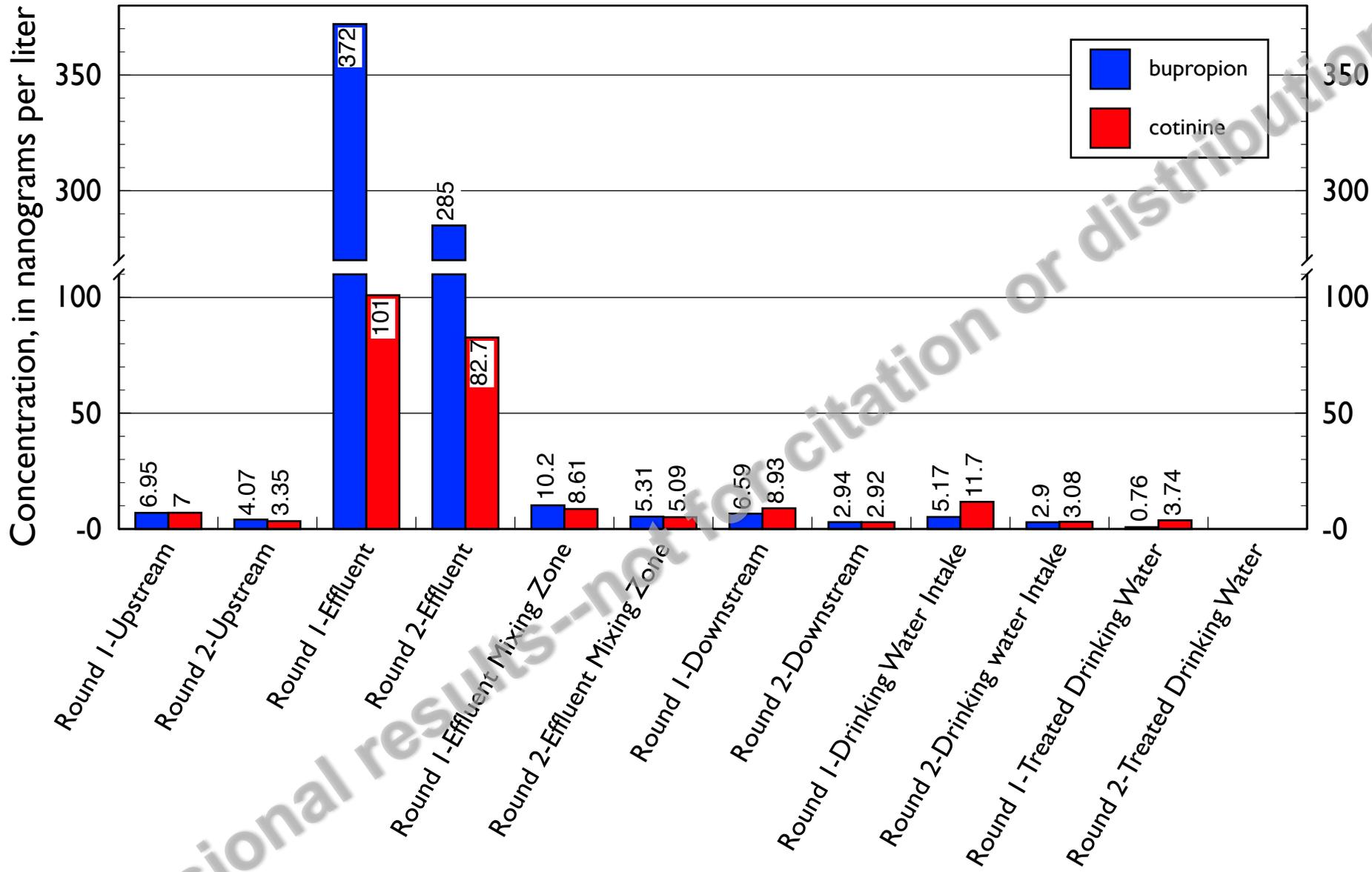


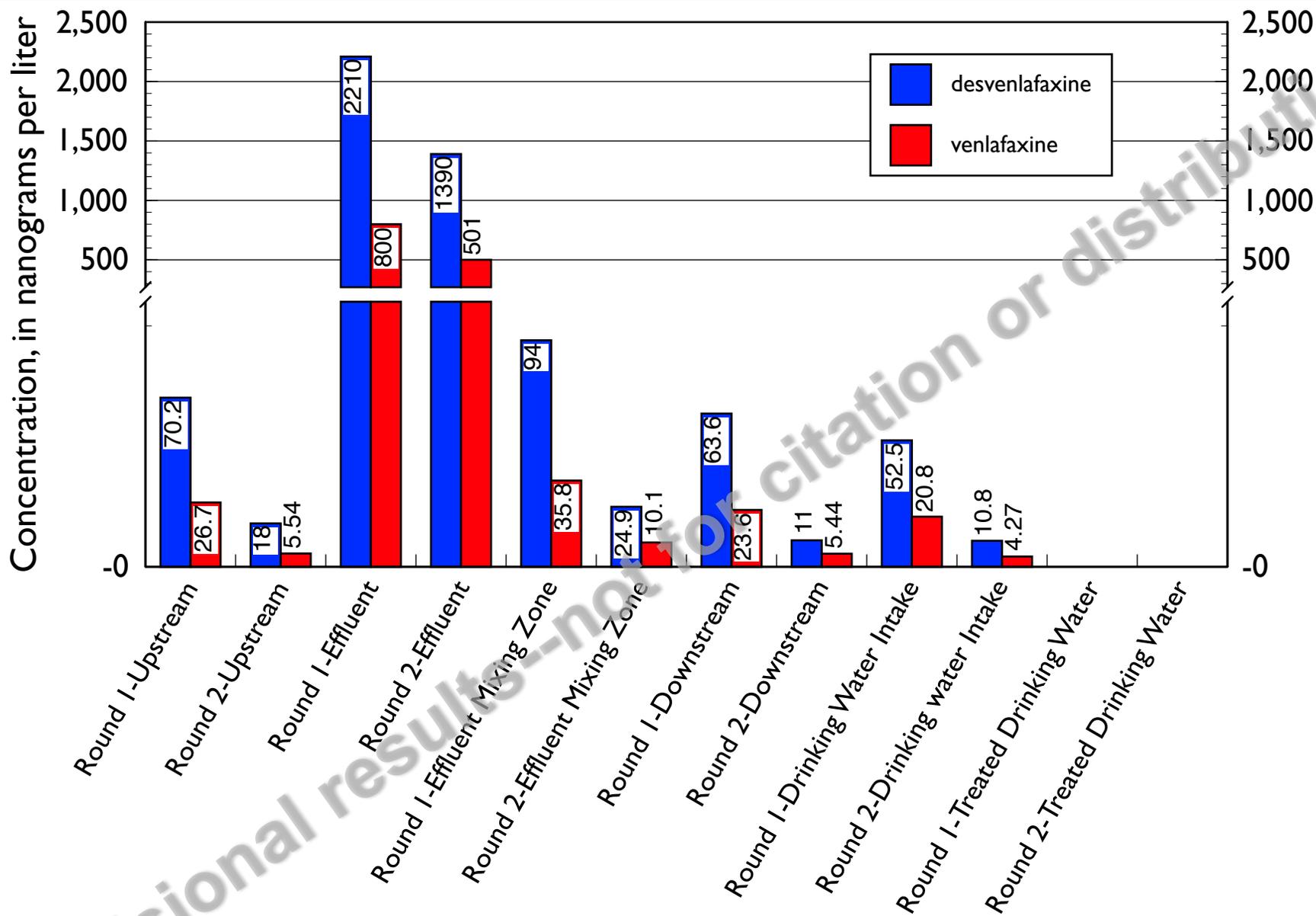
Summed Pharmaceutical Distribution



Total Detectable Pharmaceuticals of 109







Collaborators

ORD/NERL

- Glassmeyer
- Batt
- Biales
- Kostich
- Donohue
- Pfaller
- Villegas
- Vesper
- Lazorchak
- Varughese
- King
- Jones-Lepp
- Lindstrom
- Ekman

ORD/NHEERL

- Wilson
- Simmons
- Hartig
- Villeneuve

ORD/NRMRL

- Mash
- Mills
- Schenck
- Santo Domingo

Region 8

- Benson

OW

- Conerly
- Sander

OSCPP

- Boone

USGS

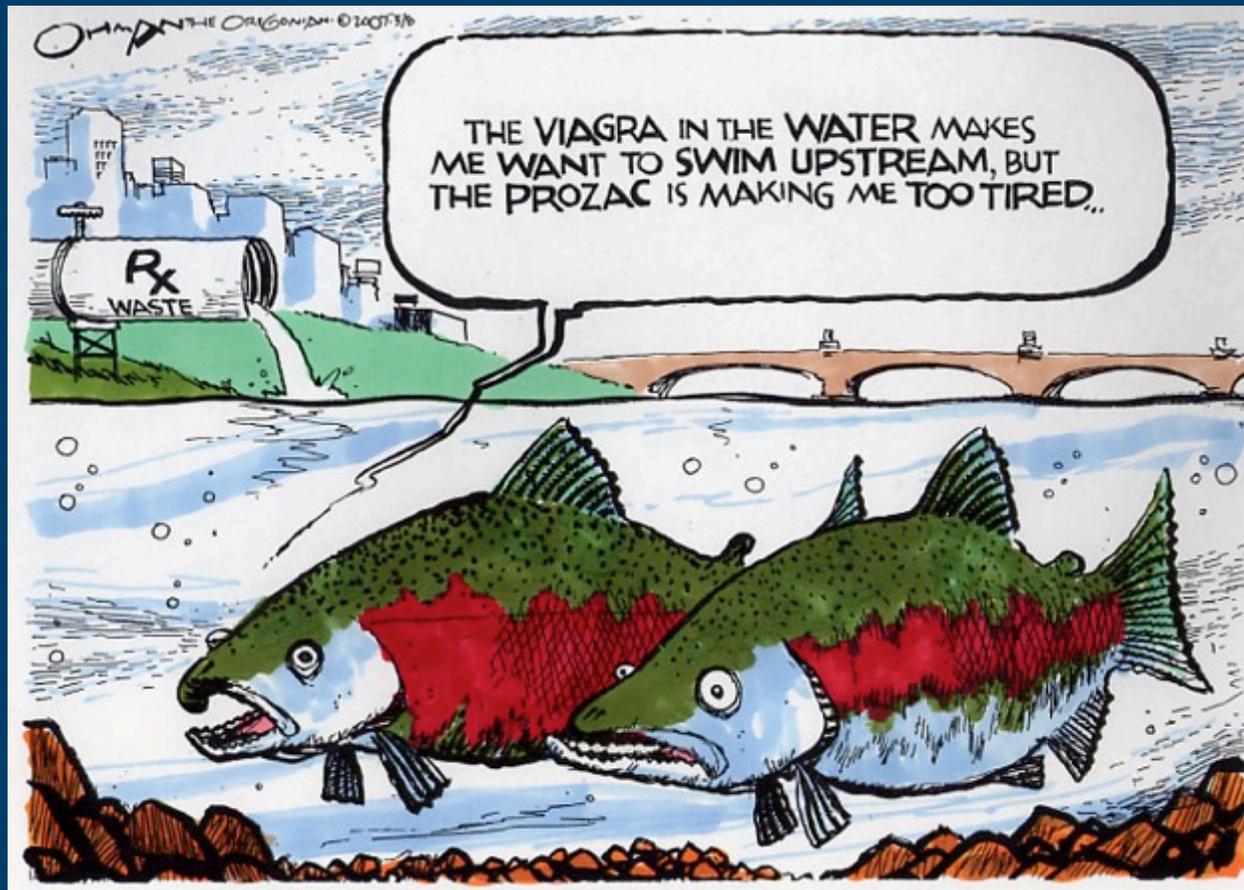
- Furlong
- Kolpin
- Buxton
- Focazio
- Meyer
- Hladik
- Alvarez

Academia

- Schultz⁺
- Hoh
- Gardinali



Questions?



“Mention of trade names is for illustrative purposes only and does not imply endorsement by the U.S. Geological Survey, the U.S. Environmental Protection Agency, or the United States Government.”

 **USGS** Edward T. Furlong (efurlong@usgs.gov)