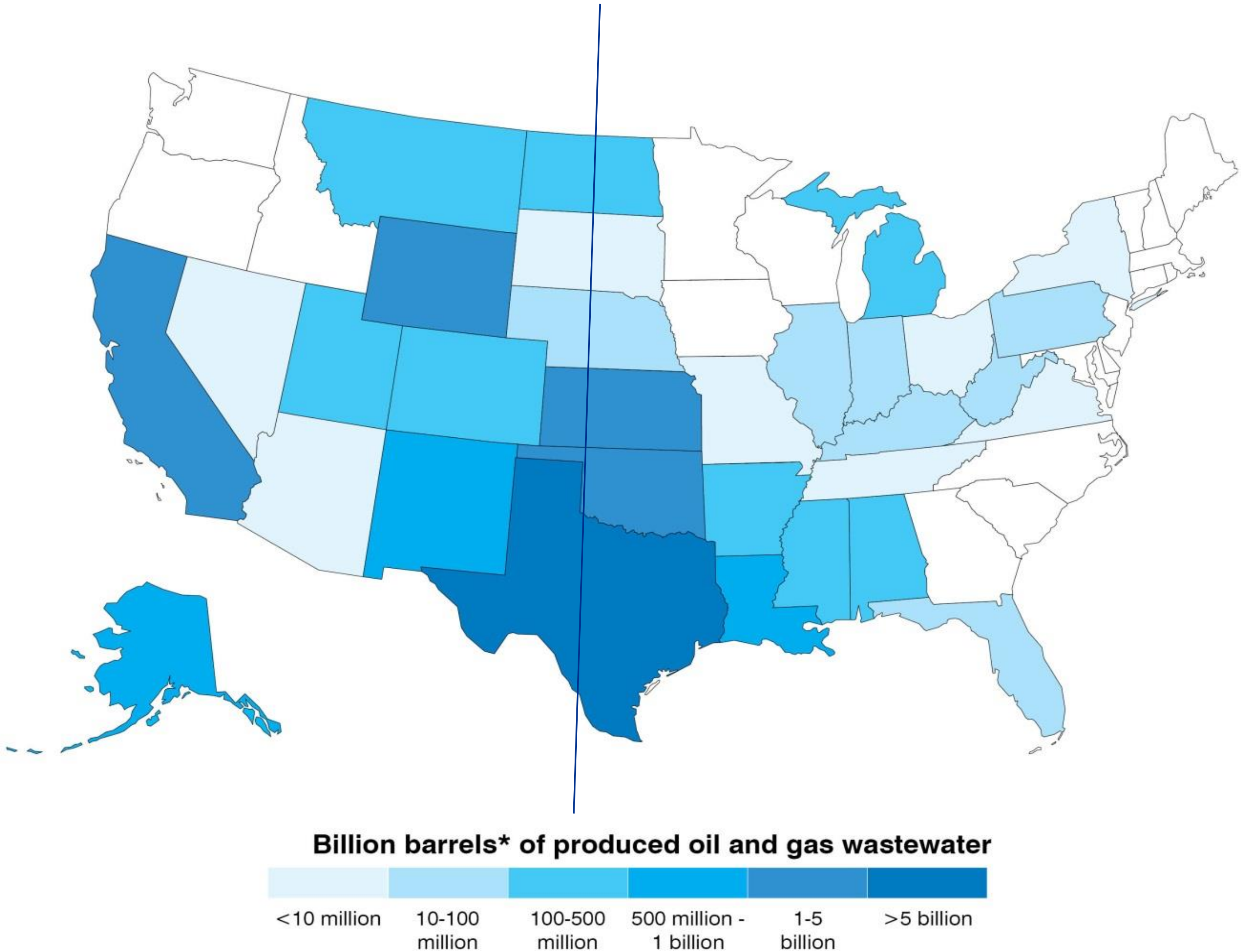
Research Strategies to Identify and Address Risks from Produced Water Reuse Outside the Oilfield

Cloelle Danforth, PhD

EDF ENVIRONMENTAL DEFENSE FUND®
Finding the ways that work

Wastewater production intensity



2018

- EPA HQ launches a study looking at state and industry interest in an expansion or modification of federal effluent limitation guidelines for PW
- Permian Basin – bottlenecks, seismicity, capacity
- New Mexico and EPA enter joint-MOU on produced water
- DOE launch of Water Security Grand Challenge (2030):

  #2. Transform the energy sector's produced water from a waste to a resource

What are the gaps?

DETECTION

We struggle with finding chemicals that may be present in oil & gas wastewater…

AWARENESS

….which means we don't know exactly which chemicals or what amounts may be present because we can't find what we aren't looking for…

EXPOSURE

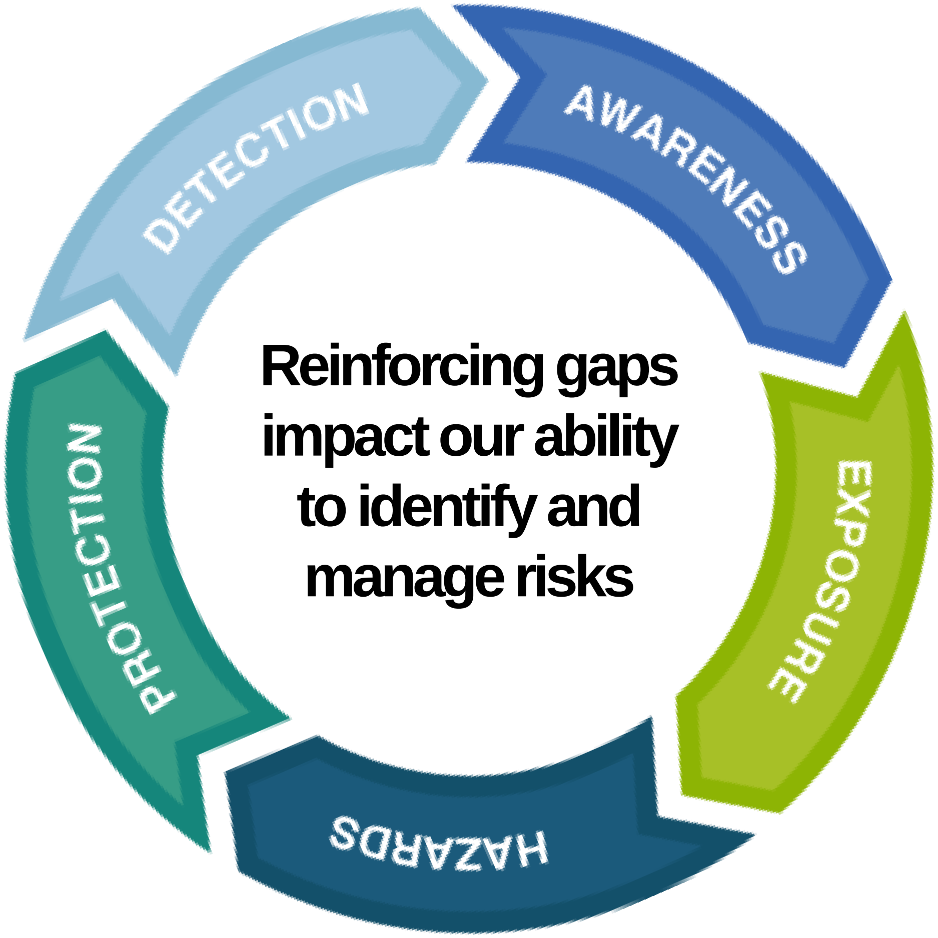
…which means we aren't researching who/what may come in contact with those chemicals…

HAZARDS

…so we can't determine whether chemicals are present at dangerous levels…

PROTECTION

…which means we don't have the information needed to treat or regulate unsafe chemicals and advance detection efforts….



EDF Science Partners

- Karl Linden, Mike Thurman, University of Colorado/Boulder
  - Biological treatment, chemical characterization
- Thomas Borch, Jens Blotevogal, J. Lucas Argueso, Colorado State University
  - Toxicity bioassay, soil health study
- Motoko Mukai, Cornell University
  - Toxicity bioassay (Zebrafish)
- Kartik Chandran, Columbia University
  - Microbial characterization for biological treatment
- Damian Helbling, Cornell University
  - Chemical Characterization
- April Gu, Cornell University
  - Toxicity bioassay
- Chris Higgins, Colorado School of Mines
  - Chemical characterization
- Nancy Denslow, University of Florida
  - Toxicity bioassay
- Bryan Brooks, Baylor University
  - Chemical characterization, toxicity identification evaluation
- Robert Tanguay, Oregon State University
  - Toxicity bioassay
- Mark Engle, Aaron Jubb, USGS
  - Chemical characterization (inorganic)
- Joe Ryan, Colorado State University
  - Database development/expansion
- Ivan Rusyn, Weihsueh Chiu, Texas A&M
  - QSAR, toxicity profiling of database

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Contents lists available at ScienceDirect

TrEAC

Emerging analytical methods for th… organic contaminants in flowback a…

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ABSTRACT

1. Introduction

Environmental Science Processes & Impacts

PAPER

Check for updates

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Environmental significance

Introduction

analytical chemistry

Identification of Pro… Fracturing Wastewa… Flight Mass Spectro…

Kurban A. Sitterley, Karl G. …

Supporting Information

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Succession of toxicity and microbiota in hydraulic fracturing flowback and produced water in the Denver–Julesburg Basin

Natalie M. Hull [a], James S. Rosenblum [a], Charles E. Robertson [b], J. Kirk Harris [c], Karl G. Linden [a,*]

HIGHLIGHTS

- Horizontal drilling and hydraulic fracturing generate flowback and produced water (FPW).
- FPW toxicity and microbiota were characterized for 220 days in the Denver-Julesburg Basin.
- Temporal trends were similar between FPW toxicity and microbial communities.
- Fracking conditions are toxic and selective with long term ecological & industrial impacts.

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Environmental Science: Processes & Impacts

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Degradation of polyethylene glycols and polypropylene glycols in microcosms simulating a spill of produced water in shallow groundwater

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ENVIRONMENTAL SIGNIFICANCE STATEMENT

Given the frequency of surface spills of produced fluids from unconventional oil and gas operations, there is a need to better characterize resulting groundwater contamination. Produced fluids are known have complex and variable chemical and microbial composition that could influence contaminant fate and transport in groundwater; however, studies on the behavior of compounds measured in produced water under environmentally-relevant conditions are limited. This study investigates degradation pathways and kinetics of the frequently-used ethoxylated surfactants polyethylene glycol and polypropylene glycol under conditions simulating a release to shallow groundwater of produced water from two hydraulically-fractured oil and gas wells at varying production times. These results may be utilized to better characterize shallow groundwater contamination following a release of produced water.

On-going work

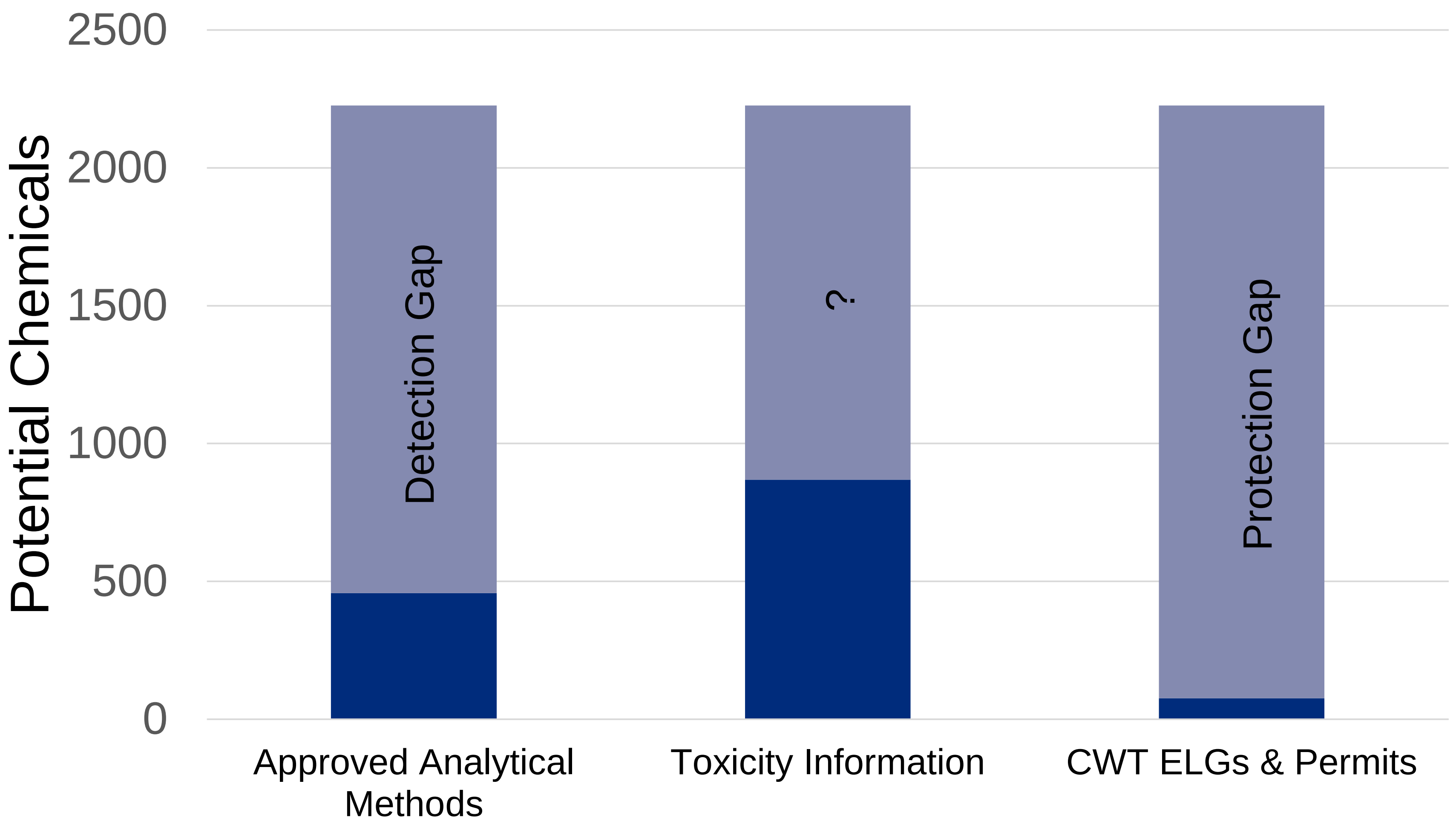
- Characterization
  - Comparing trace element quantification methods
  - Identification of recalcitrant biological compounds
  - Metabolic structure/function of MOs in various produced waters
- Treatment
  - Using enrichments to treat organics in hyper-saline wastewater; identifying MO community
  - Understanding metabolic function of halophilic microorganisms in degrading COCs in PW
- Toxicity
  - Toxicity identification evaluation of produced waters of different production ages
  - Early Life Effects of Produced Water on *Menidia beryllina*
  - Toxicity of produced water before/after various benchtop treatment schemes
  - Toxicological characterization of surface water impacted by discharge of minimally treated produced water
  - High-throughput Mechanistic Toxicity Assessment of Produced Water

Literature Review Objectives

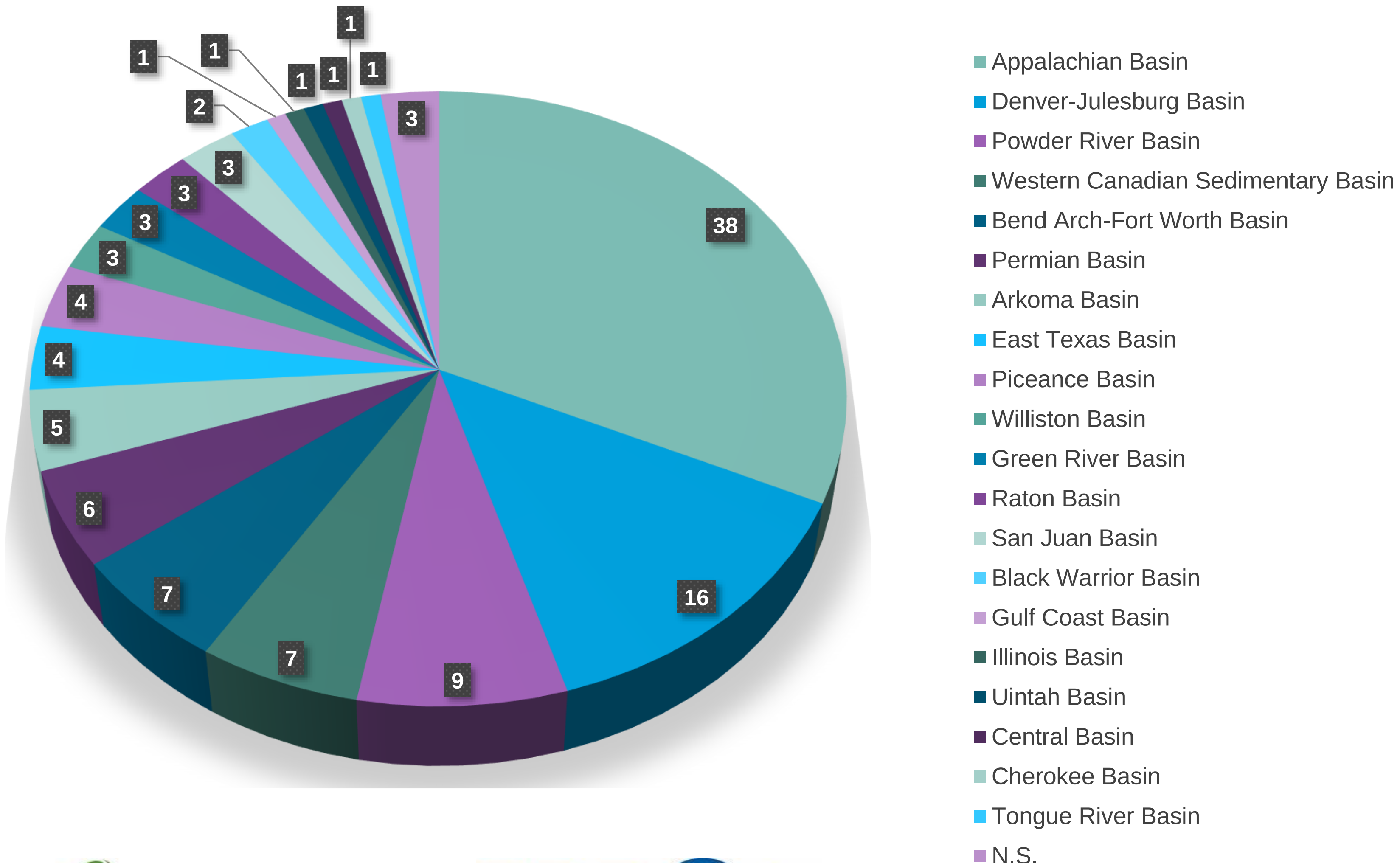
- Identify chemicals detected in wastewater from on on-shore oil and gas operations
- Prioritize based on known/unknown toxicity hazards
- Search logic:

Oil OR Gas → AND → Conventional OR Unconventional → AND → Wastewater → AND → Chemical Characterization

Data Gaps & Produced Water



Distribution of Basins



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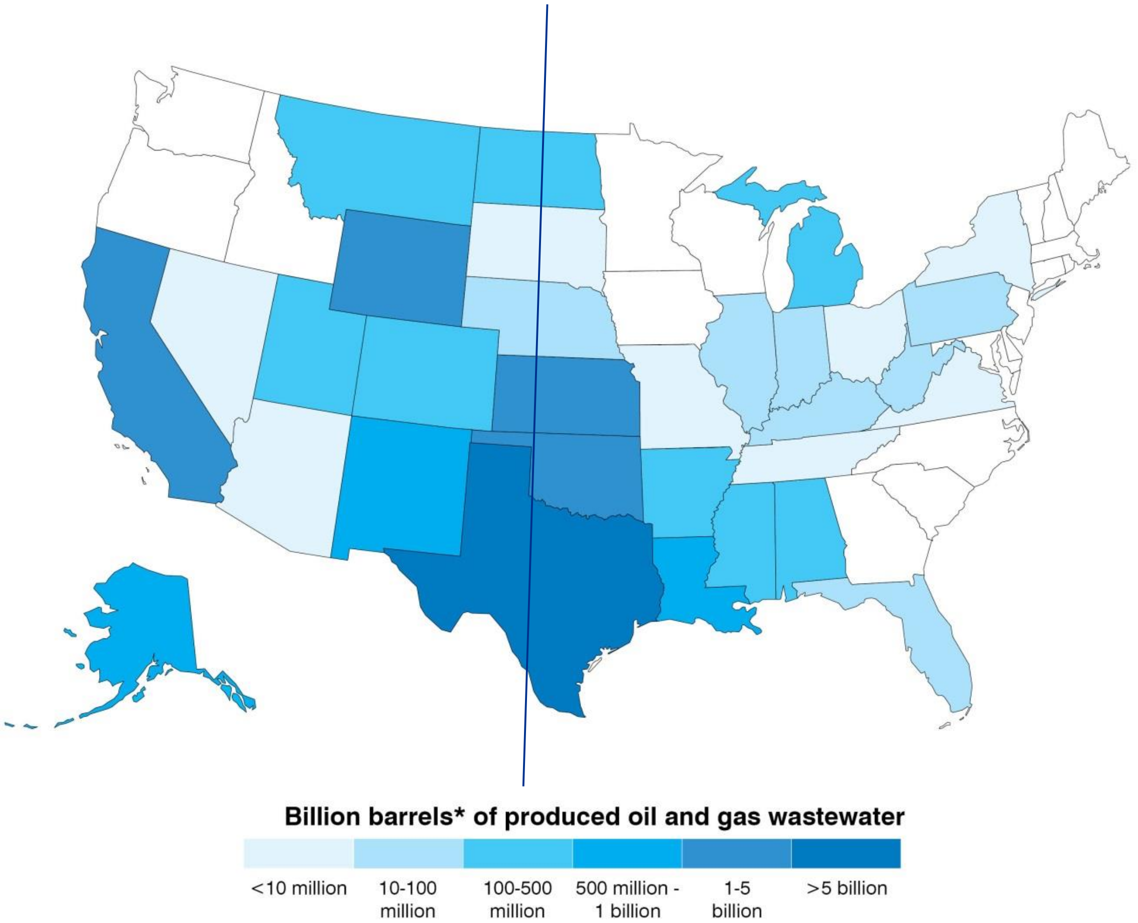
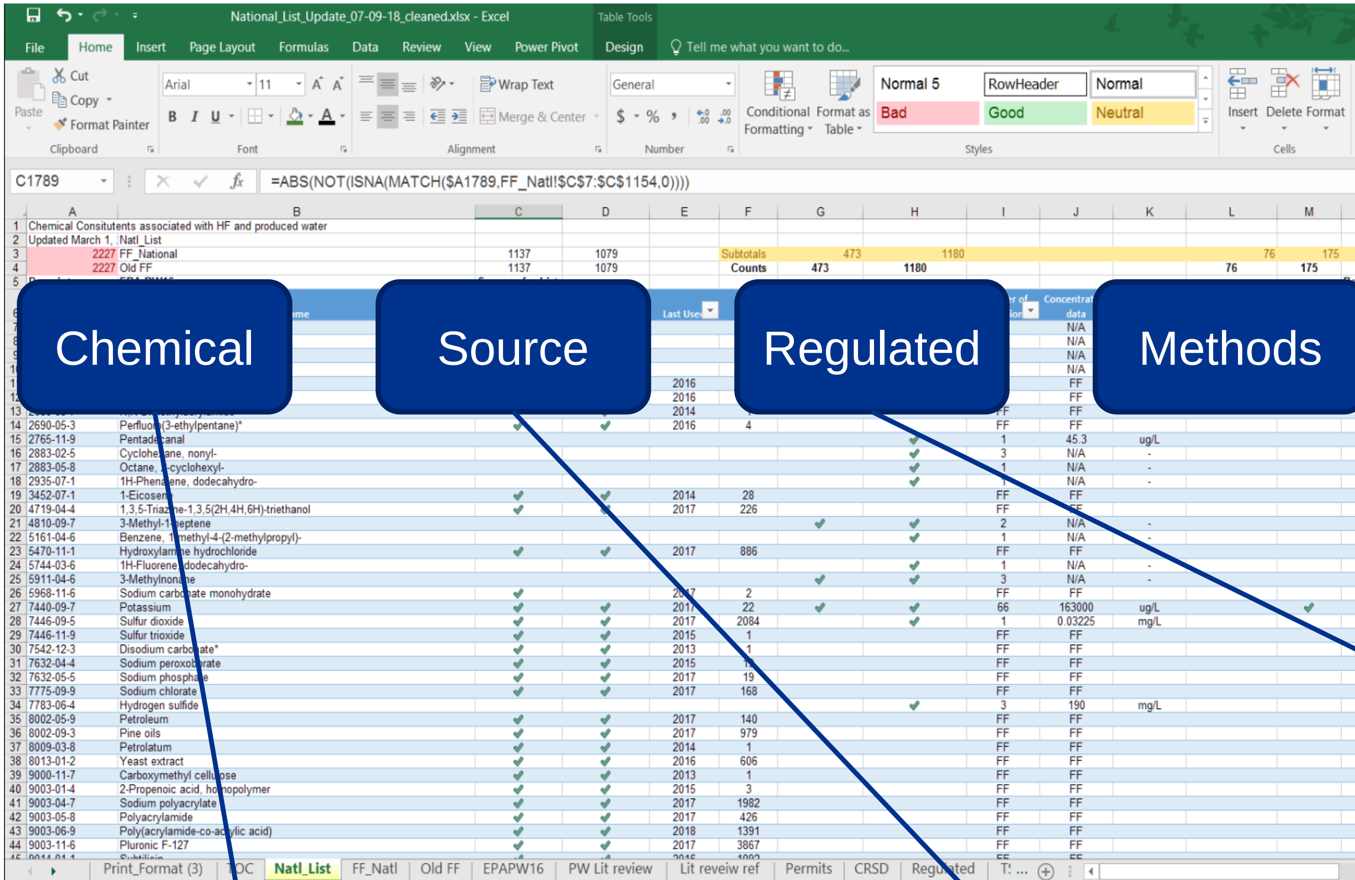
Wastewater production intensity



Chemicals Database



40 CFR 136

SW846

CWT permit

Priority Pollutant

TRI, RCRA

NPDWR or CC4

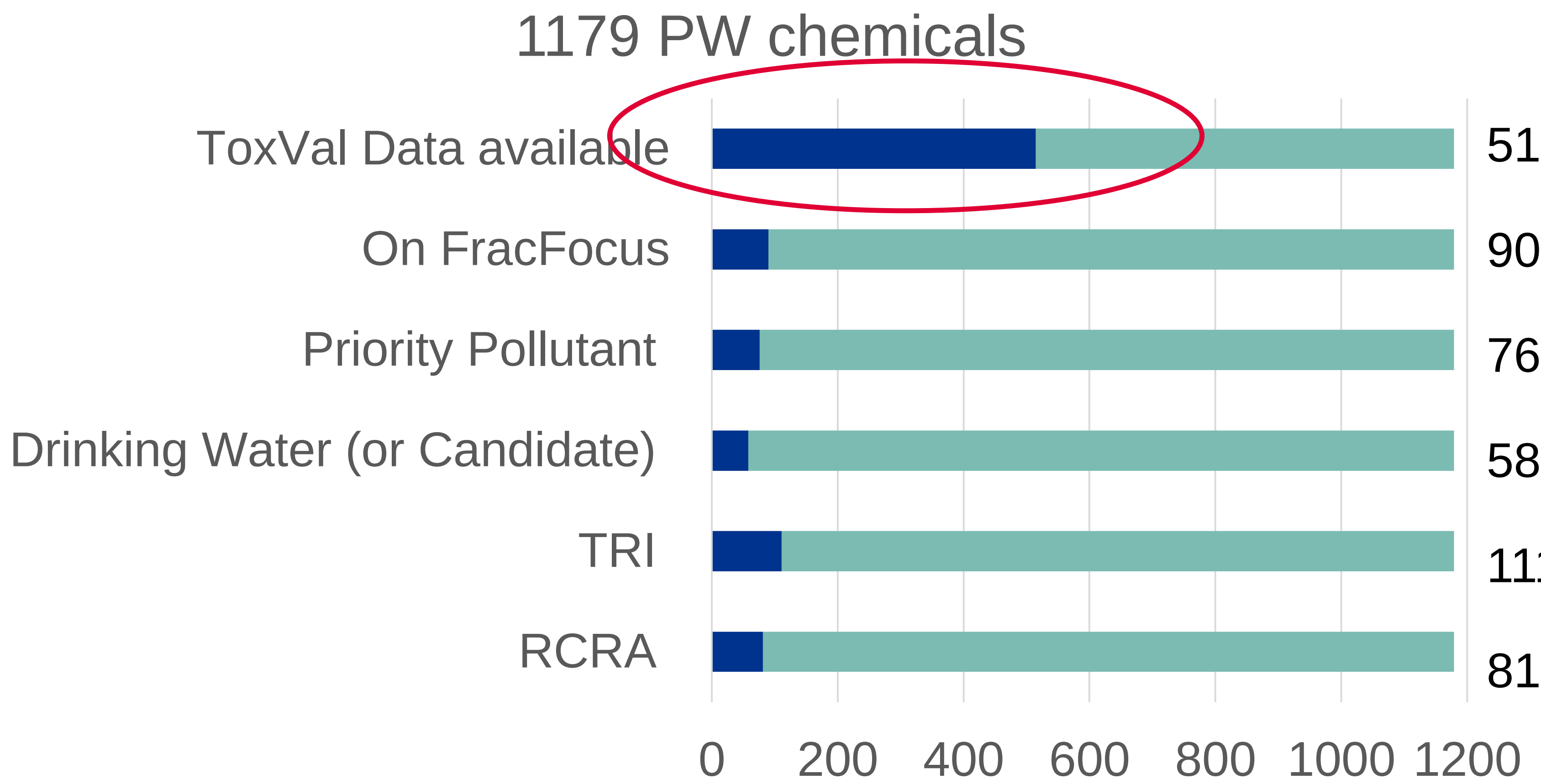
CAS

Chemical Name

FracFocus (count, date)

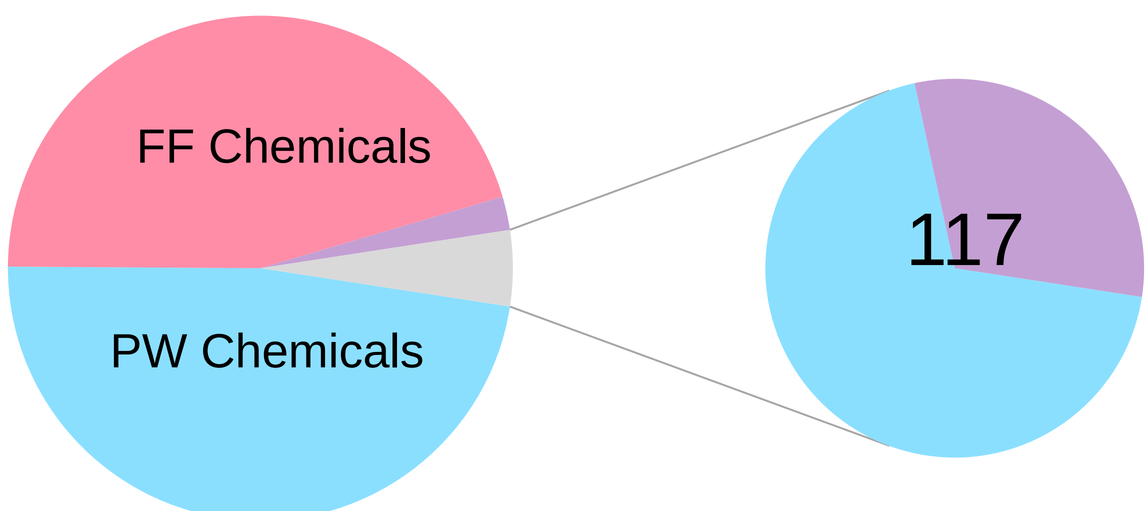
Literature (concentration, number of times sampled)

Produced water chemicals (are data-poor)

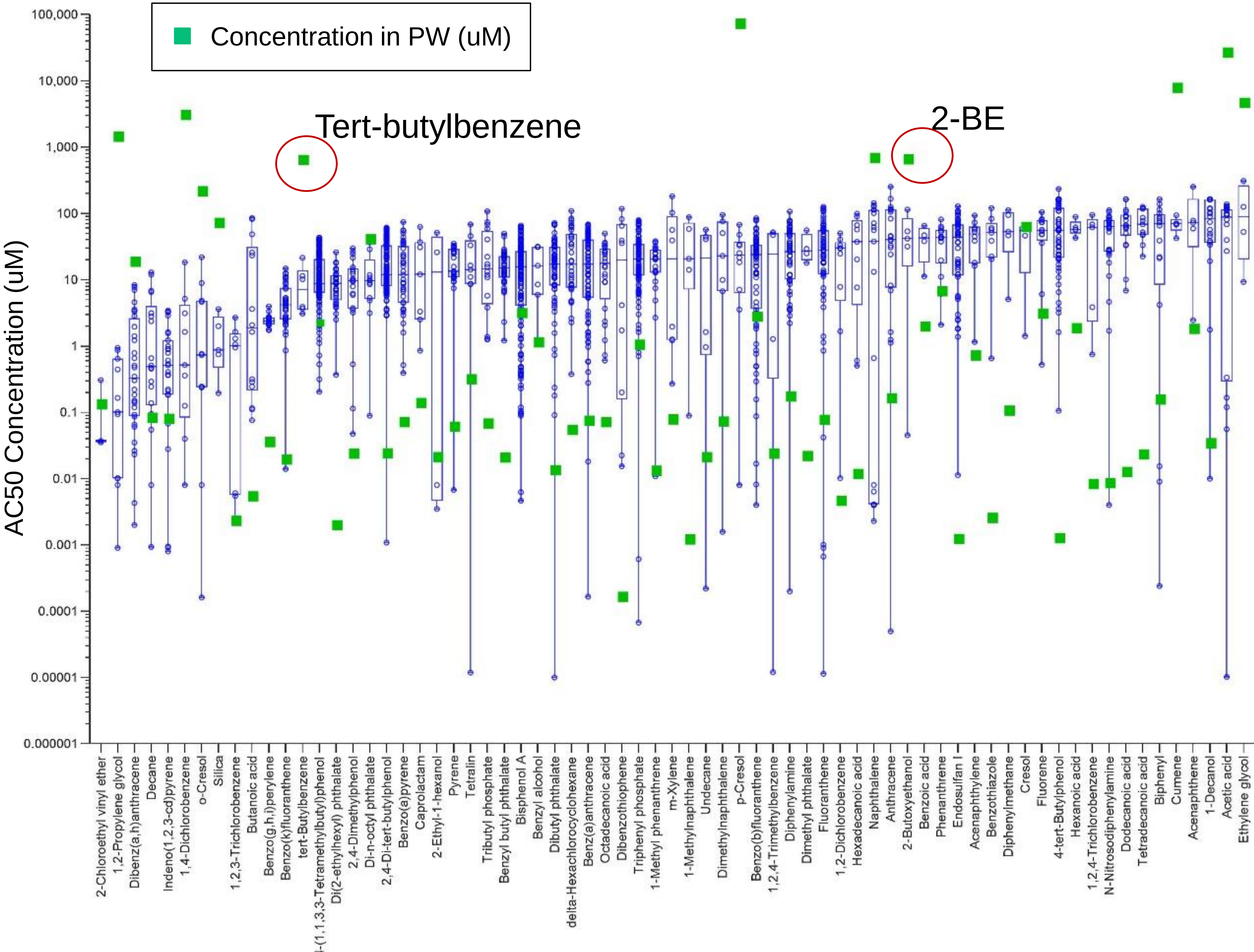


Deeper dive on subset

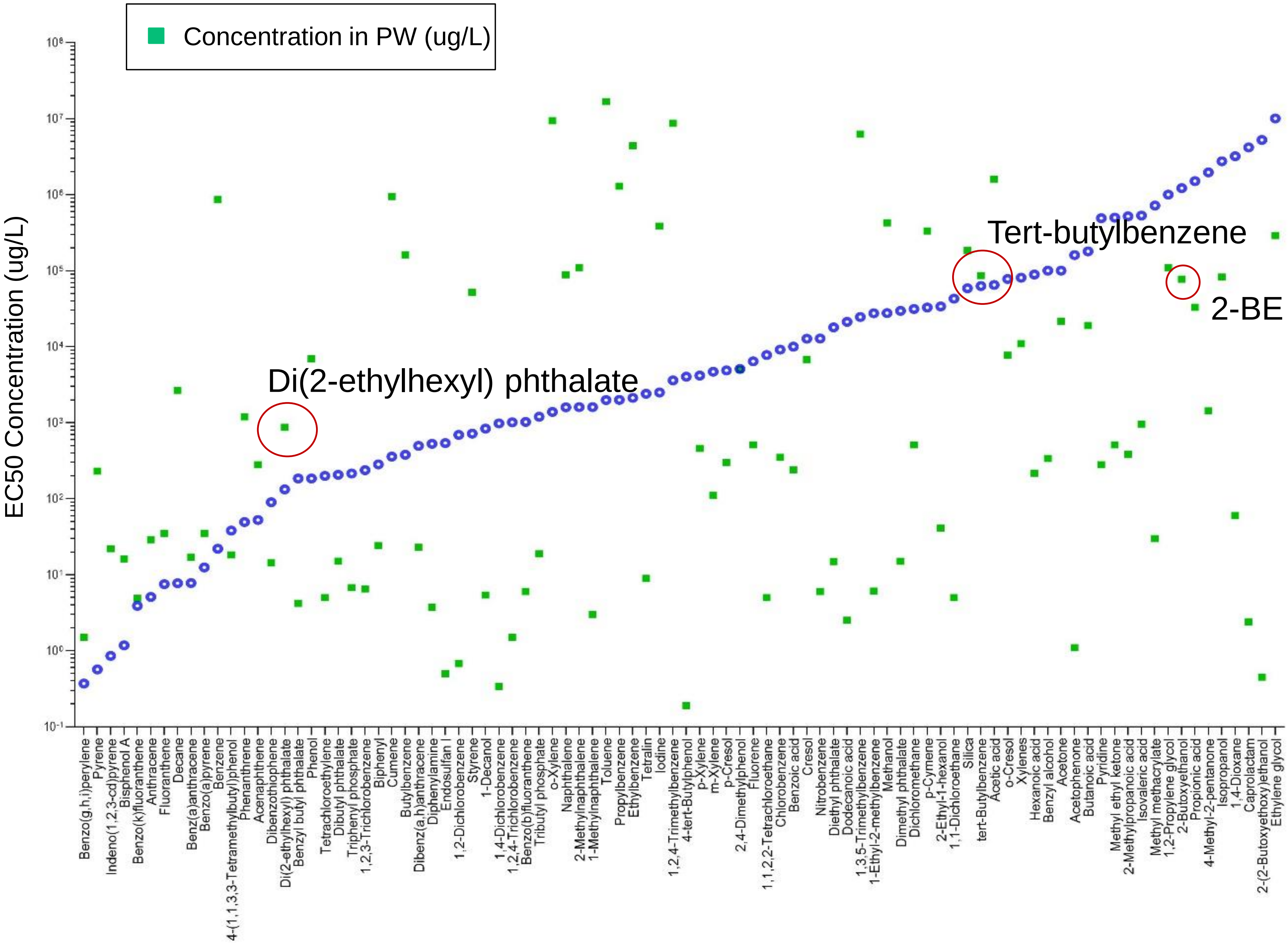
- Detected in PW more than once
- Concentration data
- Toxicity data (x2)
  - Bioassay (in vitro) – AC50
  - Ecotoxicity (in vivo) – EC50



TEXAS A&M UNIVERSITY

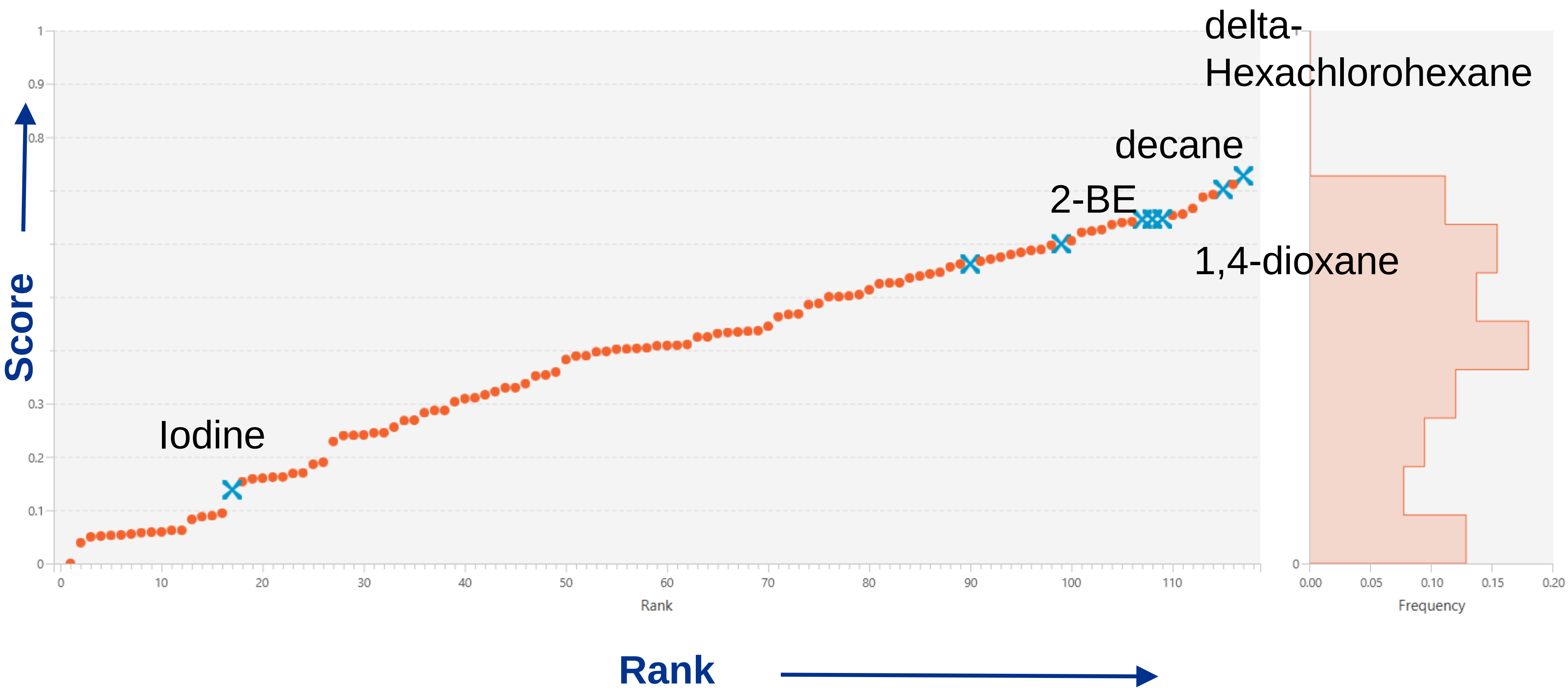


Concentration in PW (uM)
Tert-butylbenzene
2-BE
AC50 Concentration (uM)
100,000
10,000
1,000
100
10
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
2-Chloroethyl vinyl ether
1,2-Propylene glycol
Dibenz(a,h)anthracene
Decane
Indeno(1,2,3-cd)pyrene
1,4-Dichlorobenzene
o-Cresol
Silica
1,2,3-Trichlorobenzene
Butanoic acid
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
tert-Butylbenzene
4-(1,1,3,3-Tetramethylbutyl)phenol
Di(2-ethylhexyl) phthalate
2,4-Dimethylphenol
Di-n-octyl phthalate
2,4-Di-tert-butylphenol
Benzo(a)pyrene
Caprolactam
2-Ethyl-1-hexanol
Pyrene
Tetralin
Tributyl phosphate
Benzyl butyl phthalate
Bisphenol A
Benzyl alcohol
Dibutyl phthalate
delta-Hexachlorocyclohexane
Benz(a)anthracene
Octadecanoic acid
Dibenzothiophene
Triphenyl phosphate
1-Methyl phenanthrene
m-Xylene
1-Methylnaphthalene
Undecane
Dimethylnaphthalene
p-Cresol
Benzo(b)fluoranthene
1,2,4-Trimethylbenzene
Diphenylamine
Dimethyl phthalate
Fluoranthene
1,2-Dichlorobenzene
Hexadecanoic acid
Naphthalene
Anthracene
2-Butoxyethanol
Benzoic acid
Phenanthrene
Endosulfan I
Acenaphthylene
Benzothiazole
Diphenylmethane
Cresol
Fluorene
4-tert-Butylphenol
Hexanoic acid
1,2,4-Trichlorobenzene
N-Nitrosodiphenylamine
Dodecanoic acid
Tetradecanoic acid
Biphenyl
Cumene
Acenaphthene
1-Decanol
Acetic acid
Ethylene glycol



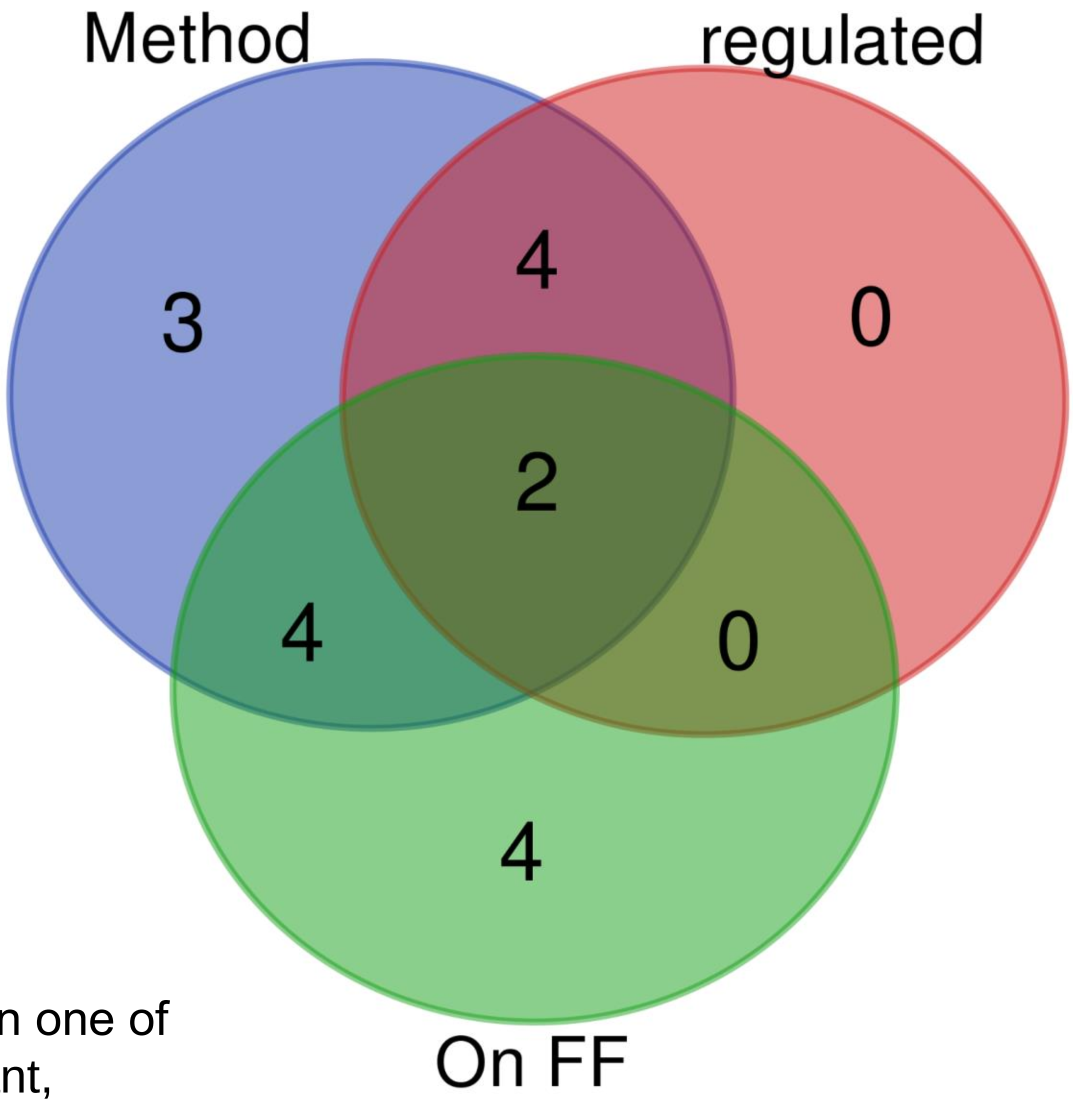
Concentration in PW (ug/L)
EC50 Concentration (ug/L)
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
Di(2-ethylhexyl) phthalate
Tert-butylbenzene
2-BE
Benzo(g,h,i)perylene
Pyrene
Indeno(1,2,3-cd)pyrene
Bisphenol A
Benzo(k)fluoranthene
Anthracene
Fluoranthene
Decane
Benz(a)anthracene
Benzo(a)pyrene
Benzene
4-(1,1,3,3-Tetramethylbutyl)phenol
Phenanthrene
Acenaphthene
Dibenzothiophene
Di(2-ethylhexyl) phthalate
Benzyl butyl phthalate
Phenol
Tetrachloroethylene
Dibutyl phthalate
Triphenyl phosphate
1,2,3-Trichlorobenzene
Biphenyl
Cumene
Butylbenzene
Dibenz(a,h)anthracene
Diphenylamine
Endosulfan I
1,2-Dichlorobenzene
Styrene
1-Decanol
1,4-Dichlorobenzene
1,2,4-Trichlorobenzene
Benzo(b)fluoranthene
Tributyl phosphate
o-Xylene
Naphthalene
2-Methylnaphthalene
1-Methylnaphthalene
Toluene
Propylbenzene
Ethylbenzene
Tetralin
Iodine
1,2,4-Trimethylbenzene
4-tert-Butylphenol
p-Xylene
m-Xylene
p-Cresol
2,4-Dimethylphenol
Fluorene
1,1,2,2-Tetrachloroethane
Chlorobenzene
Benzoic acid
Cresol
Nitrobenzene
Diethyl phthalate
Dodecanoic acid
1,3,5-Trimethylbenzene
1-Ethyl-2-methylbenzene
Methanol
Dimethyl phthalate
Dichloromethane
p-Cymene
2-Ethyl-1-hexanol
1,1-Dichloroethane
Silica
tert-Butylbenzene
Acetic acid
o-Cresol
Xylenes
Hexanoic acid
Benzyl alcohol
Acetone
Acetophenone
Butanoic acid
Pyridine
Methyl ethyl ketone
2-Methylpropanoic acid
Isovaleric acid
Methyl methacrylate
1,2-Propylene glycol
2-Butoxyethanol
Propionic acid
4-Methyl-2-pentanone
Isopropanol
1,4-Dioxane
Caprolactam
2-(2-Butoxyethoxy)ethanol
Ethylene glycol

ToxPi

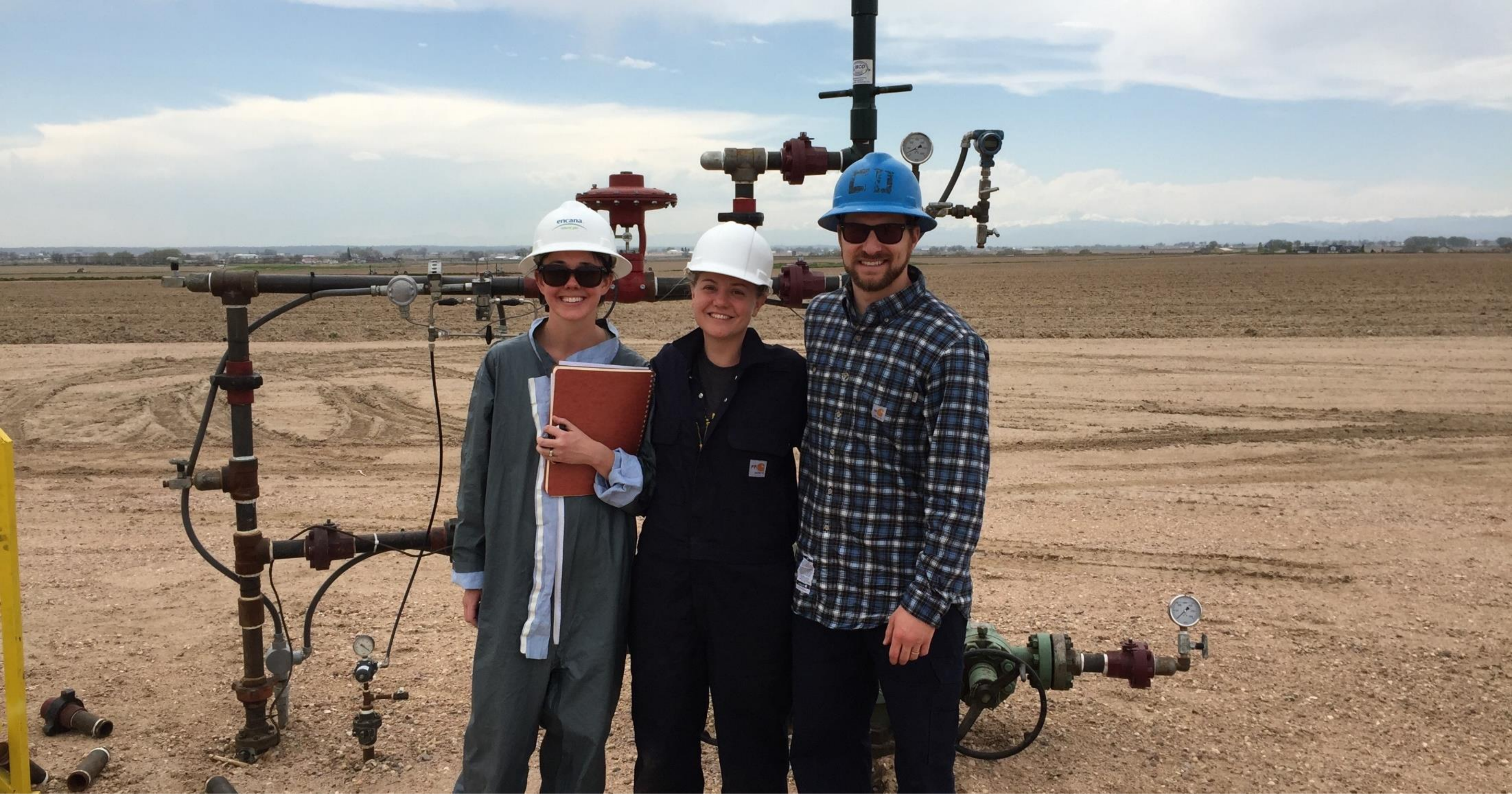

delta-
Hexachlorohexane
decane
2-BE
1,4-dioxane
Iodine
Score
Rank
Frequency
Rank

Top 20

- 10 are on FF
- 6 are "regulated"**
- 13 have standard method



**"Regulated" defined as being on one of the following lists: Priority Pollutant, RCRA, TRI, EPA DW/HA, CCL4



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