

Contaminants of Emerging Concern: Challenges going forward –

What we know

What we don't know

What we wish we knew

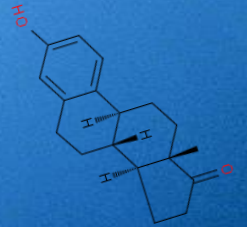
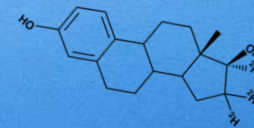
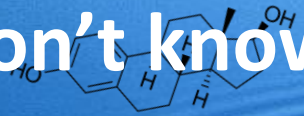
What we dare not ask

oh yeah... what we need to know in relation to Title 5

George Heufelder

Massachusetts Alternative Septic System Test Center

Barnstable County Department of Health and Environment



The data and projects discussed here were funded in part by the Massachusetts Department of Environmental Protection with funds from the United States Environmental Protection Agency under a Section 319 competitive grant. The contents of this presentation do not necessarily reflect the views or policies of the departments mentioned nor does the mention of any product trade name constitute and endorsement.



A large, complex nebula is the central focus of the image. It features a dense network of glowing filaments and clouds in various colors, including bright green, yellow, and orange, set against a deep black background filled with numerous small, distant stars. The nebula's structure is intricate, with many smaller clumps and voids. The text "Where to begin" is centered over the nebula in a bold, black, sans-serif font.

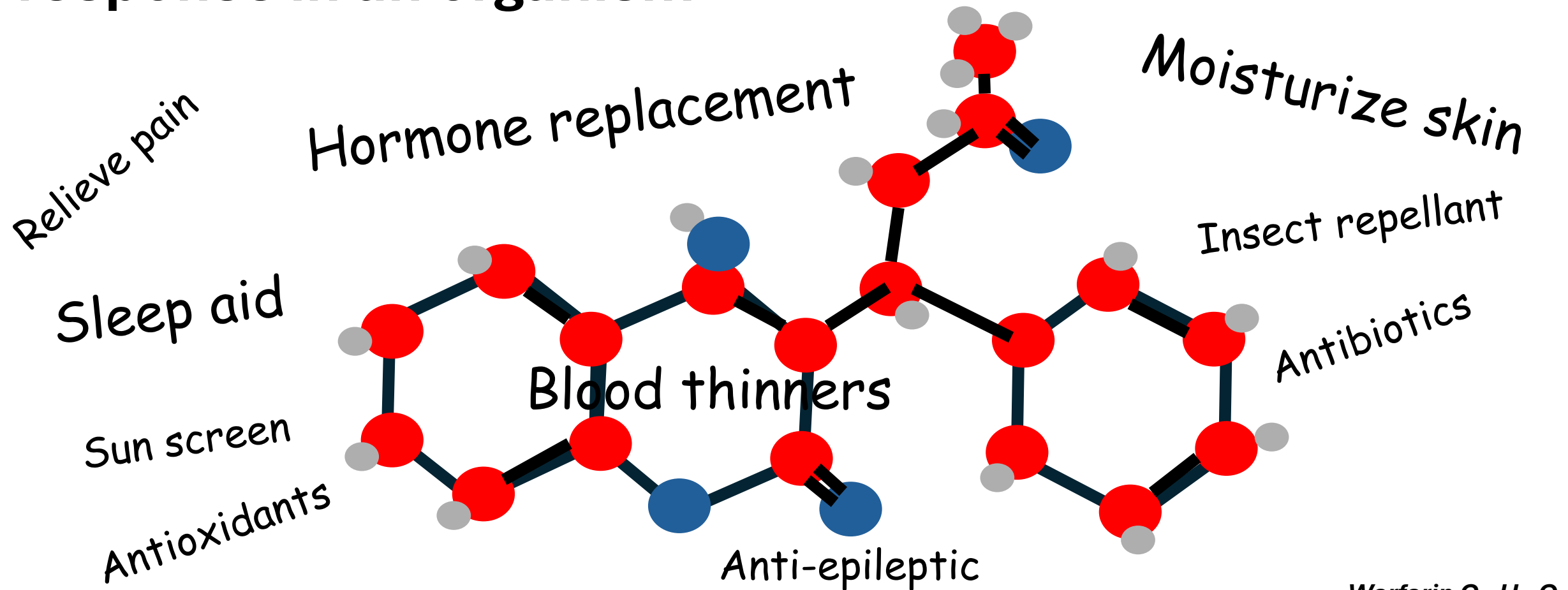
**Where to
begin**

Coming to terms -
Keeping the acronyms
straight

PPCP vs CEC

Pharmaceutical or personal care products are subset of the wider class Contaminants of Emerging Concern which includes PPCPs ***and*** organic compounds manufactured (or made in nature) for various purposes such as plasticizers, fire retardants, lubricants, hormones and more.

A pharmaceutical or personal care product is an arrangement of atoms made in nature or by manufacture to affect a desired physiological response in an organism



Warfarin $C_{19}H_{16}O_4$



WHY DO WE CARE?

4 reasons

Reason 1

Although therapeutic doses are rarely encountered, the effect of long-term exposure to many contaminants of emerging concern is not known

(although some animal studies suggest some negative effects)



exposure



**“What hath God wrought” – the first
message typed out in morse code (May 24,
1884)**

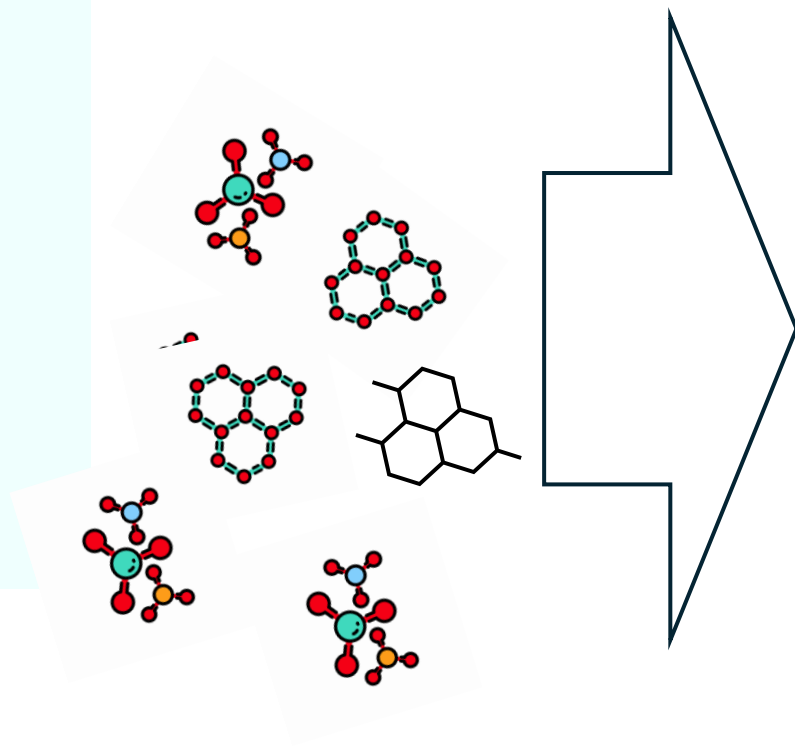
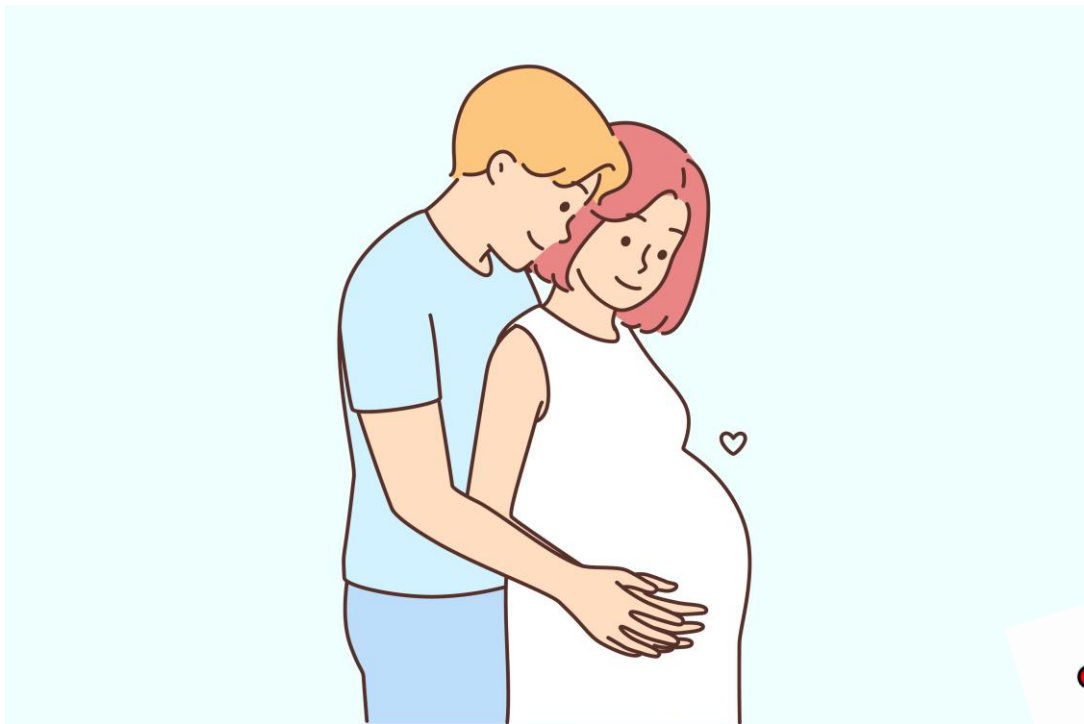
**“What hath man wrought”
David Lawrence U.S, News (1945)**

**And muttered nearly every day
since then**



White matter microstructural integrity mediates associations between prenatal endocrine-disrupting chemicals exposure and intelligence in adolescents

Our results showed significant associations between prenatal exposure to PFAS and phthalates with changes in specific fronto-parietal regions of the adolescent male brain, including reduced cortical thickness in the inferior frontal gyrus and right superior parietal cortex, which are involved in language, memory, and executive function. A dose–response association was observed, with higher levels of PFAS and PAE exposure modulating altered white-matter fiber integrity in the superior cerebellar peduncle and inferior cerebellar peduncle of the male and female adolescent brains. In addition, higher levels of prenatal exposure to EDCs were associated with lower IQ scores in adolescents. Mediation analyses further revealed that white-matter microstructure of inter-hemispheric and cerebellar fibers mediated the association between prenatal EDC exposure and adolescent IQ scores in female adolescents. Our multimodal human neuroimaging findings suggest that prenatal exposure to EDCs may have long-lasting effects on neuroanatomical development, neural fiber connectivity, and intelligence in adolescents, and highlight the importance of using advanced diffusion imaging techniques, including DKI and NODDI, to detect neurodevelopmental changes and their brain behavioral consequences with the risks associated with these environmental exposures.



Reason 2

Collapse of a fish population after exposure to a synthetic estrogen



Karen A. Kidd ^{*}, [†], Paul J. Blanchfield ^{*}, Kenneth H. Mills ^{*}, Vince P. Palace ^{*},
Robert E. Evans ^{*}, James M. Lazorchak [‡], and Robert W. Flick [‡]

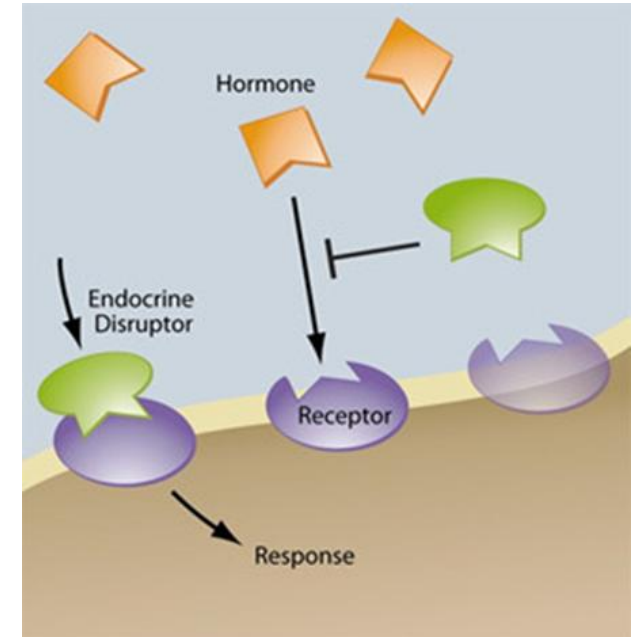


The effects of
PPCPs in the
environment can be
expressed at very
low levels



How does this happen? It turns out that you actually can fool Mother Nature.

Many hormones are regulated by feedback loops where the concentration of the hormone limits its further production.



Some CEC “lock into” receptors and hence may sent the wrong signal to the body, either shutting off or ramping up the production of the hormone.

Reason 3



Because it turns out that you actually can fool Mother Nature.



Reason 3 (continued)

Humans may not get a good dose but they do !



Reproductive effects of endocrine disrupting chemicals, bisphenol-A and 17 β -oestradiol, on *Cerastoderma edule* from south-west England: field study and laboratory exposure



Intersex occurrence in rainbow trout (*Oncorhynchus mykiss*) male fry chronically exposed to ethynylestradiol.



Carbamazepine disrupts molting hormone signaling and inhibits molting and growth of *Eriocheir sinensis* at environmentally relevant concentrations.

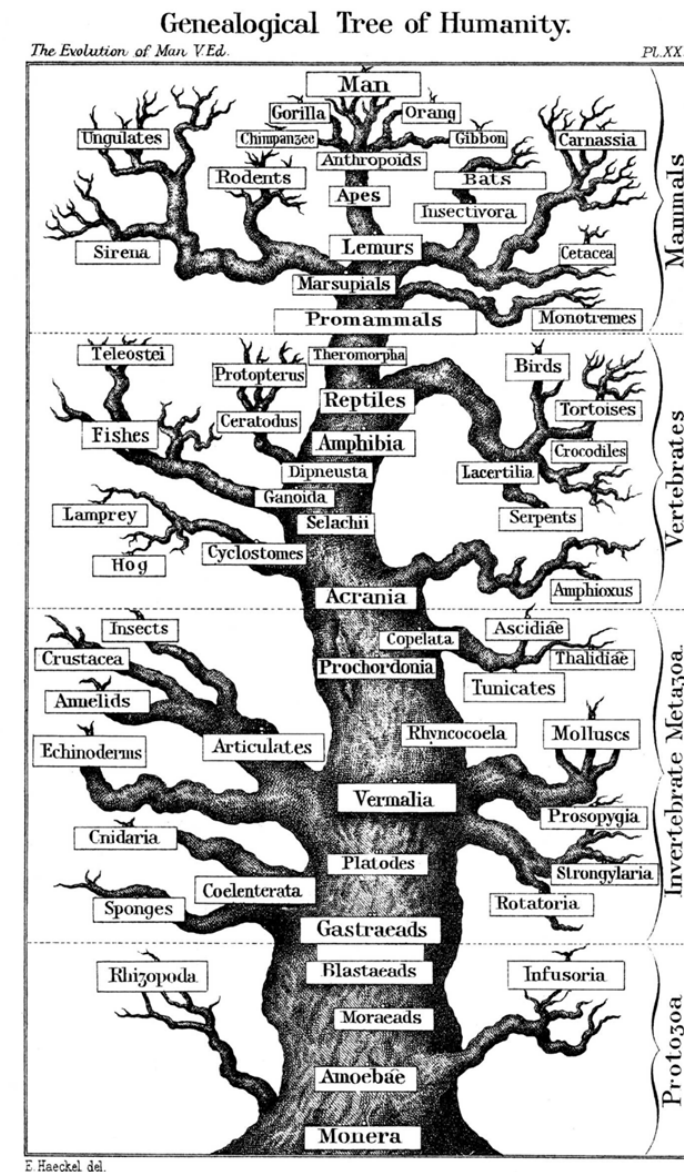


Effect of polycyclic musk compounds on aquatic organisms: A critical literature review supplemented by own data



BACKWARDS
COMPATIBLE

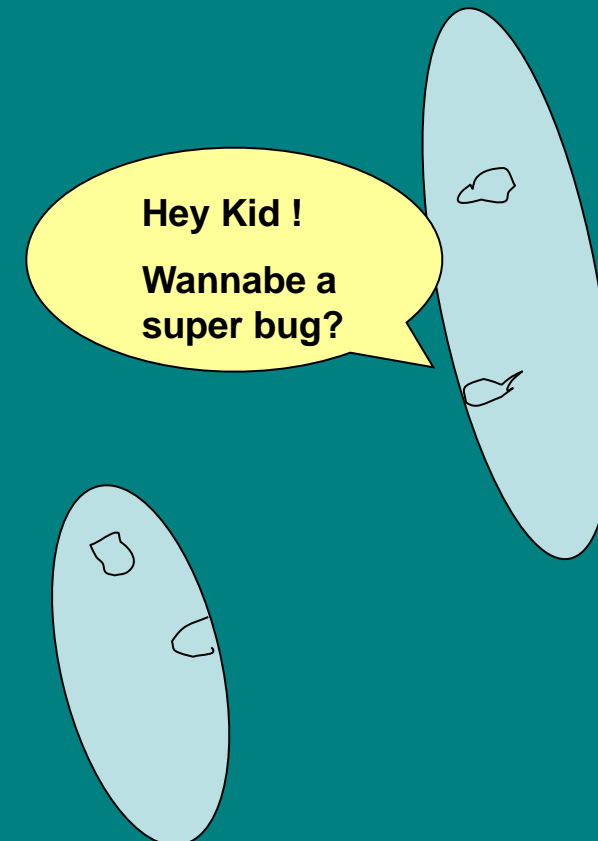
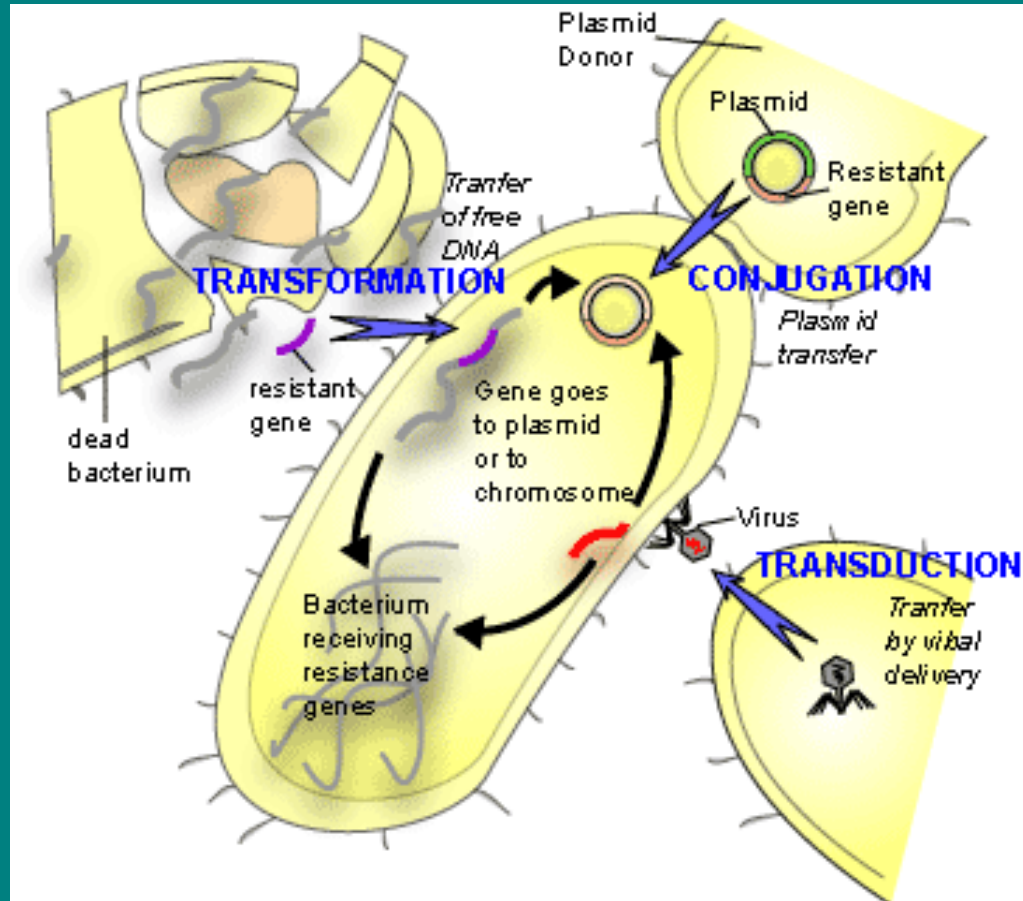
Like backward compatible software, those chemicals that are “programmed” to effect physiological changes in primitive animals can also effect more complex animals and visa-versa.



4

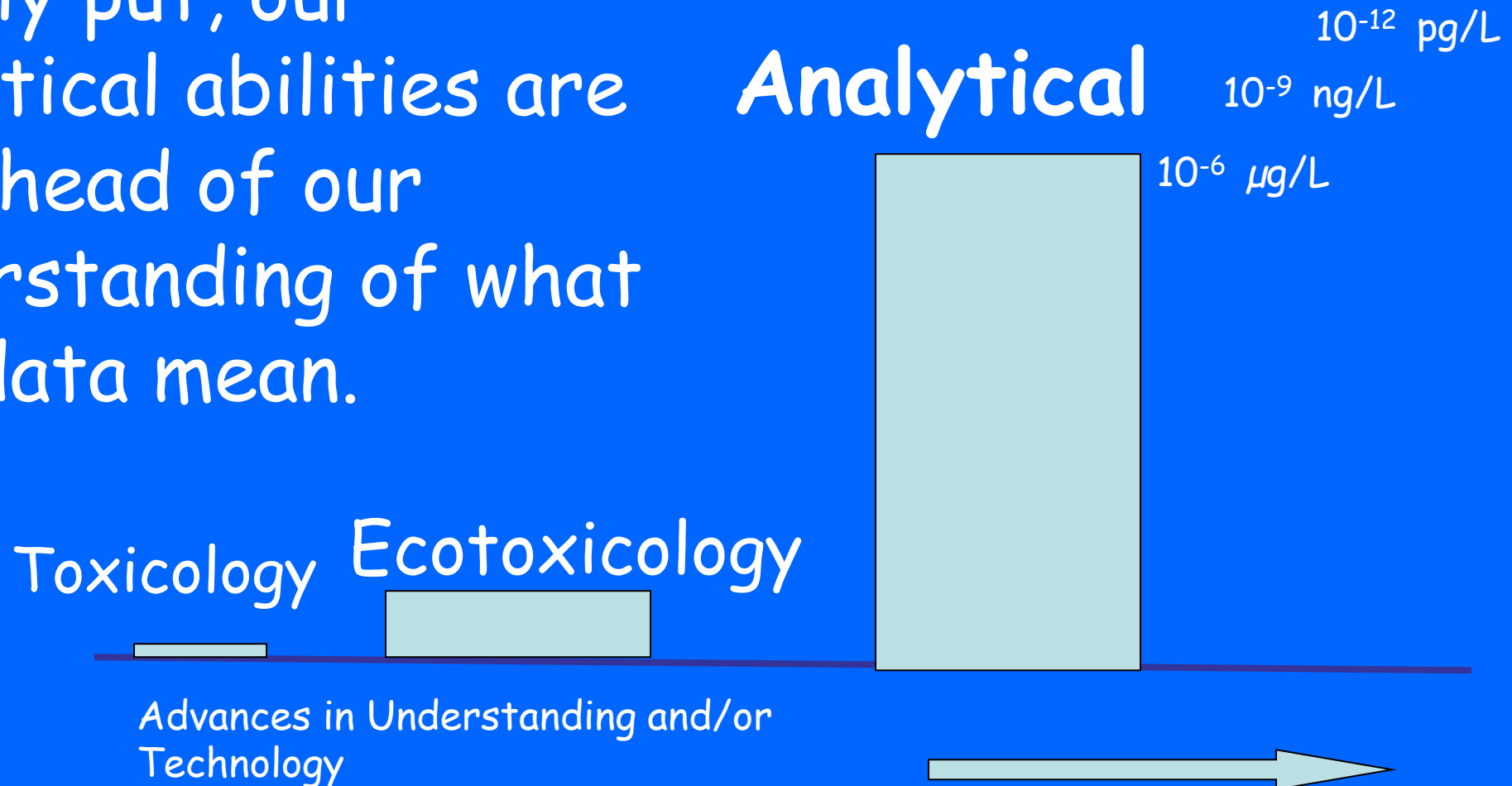
Issues with Antimicrobials/antibacterials

- Inducing antibiotic resistance (more of an issue with spreading of animal manure -veterinary medications)
- Direct effect on wastewater biology (generally episodic in nature)



SHORT STORY ?

Simply put, our analytical abilities are far ahead of our understanding of what the data mean.



Pathways of PPCPs to the septic system



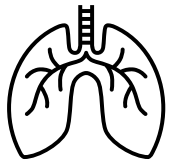
DIRECT



DEPOSIT



Inhalant



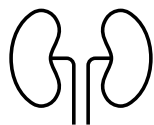
Body

Ingestion

Blood ← Absorption → Blood

Liver

Gall Bladder



Kidney

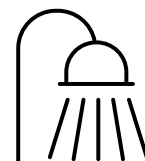
Poop

Urine

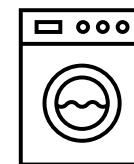


Septic System

Dermal
application



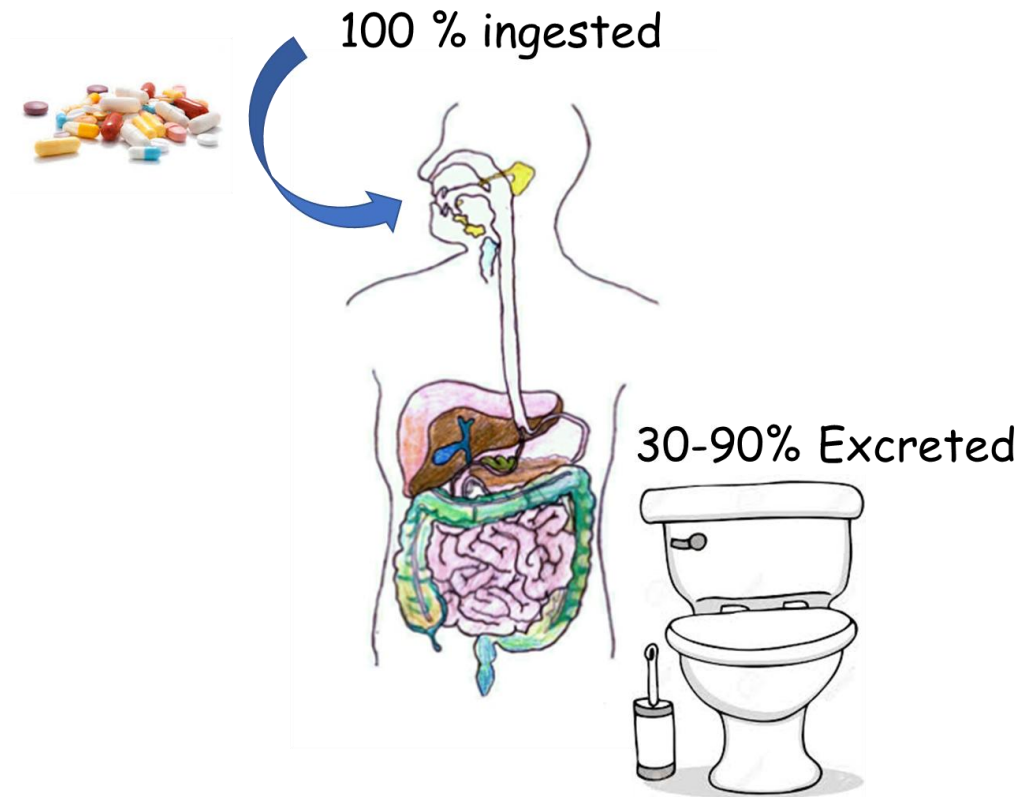
Washloads





Take Home Messages

- Many of the drugs we take pass through our body to some extent unused and exit unchanged
- Some pharmaceuticals are transformed in our bodies and daughter products are passed
- Some “natural” products (estrogen, androgen and others) exit our body and may also exhibit environmental impacts





After the flush

**Fate and
transport of
PPCPs in the
septic system**



Septic Tank - first stop

Treatment mechanisms

- **Adsorption to solids and grease**
- **Anaerobic digestion (very few studies performed)**

Soil Treatment area a.k.a. Leachfield

**Where most of the interesting
transformations happen.**

Treatment mechanisms

- **Sorption to soils**
- **Aerobic biodegradation**
- **Volatilization**
- **Transformation**

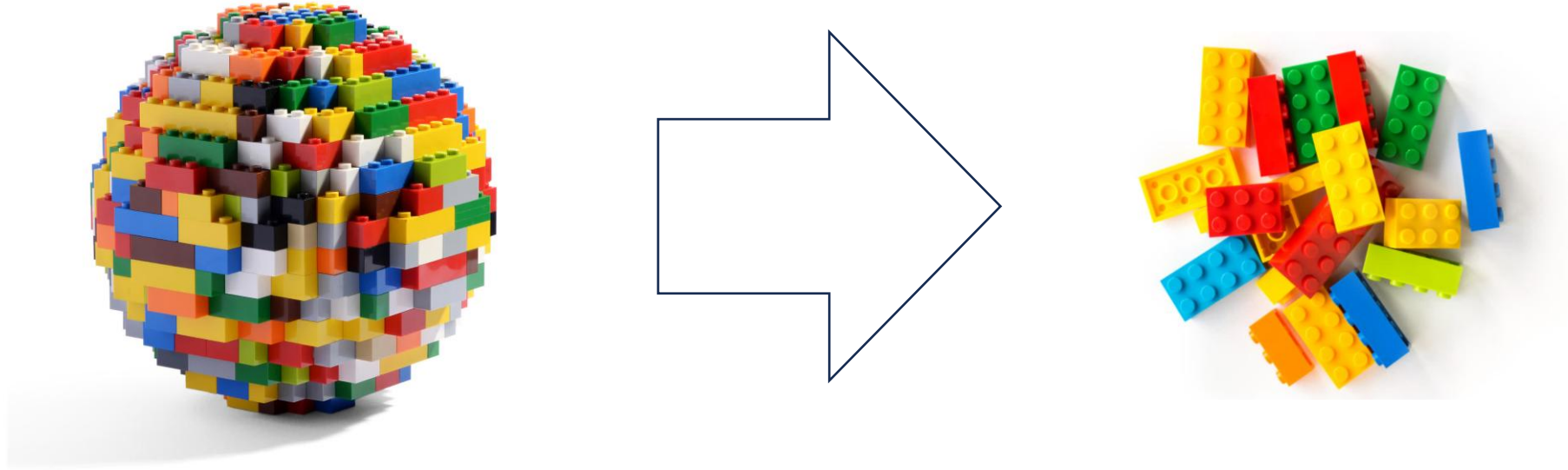
The voyage begins





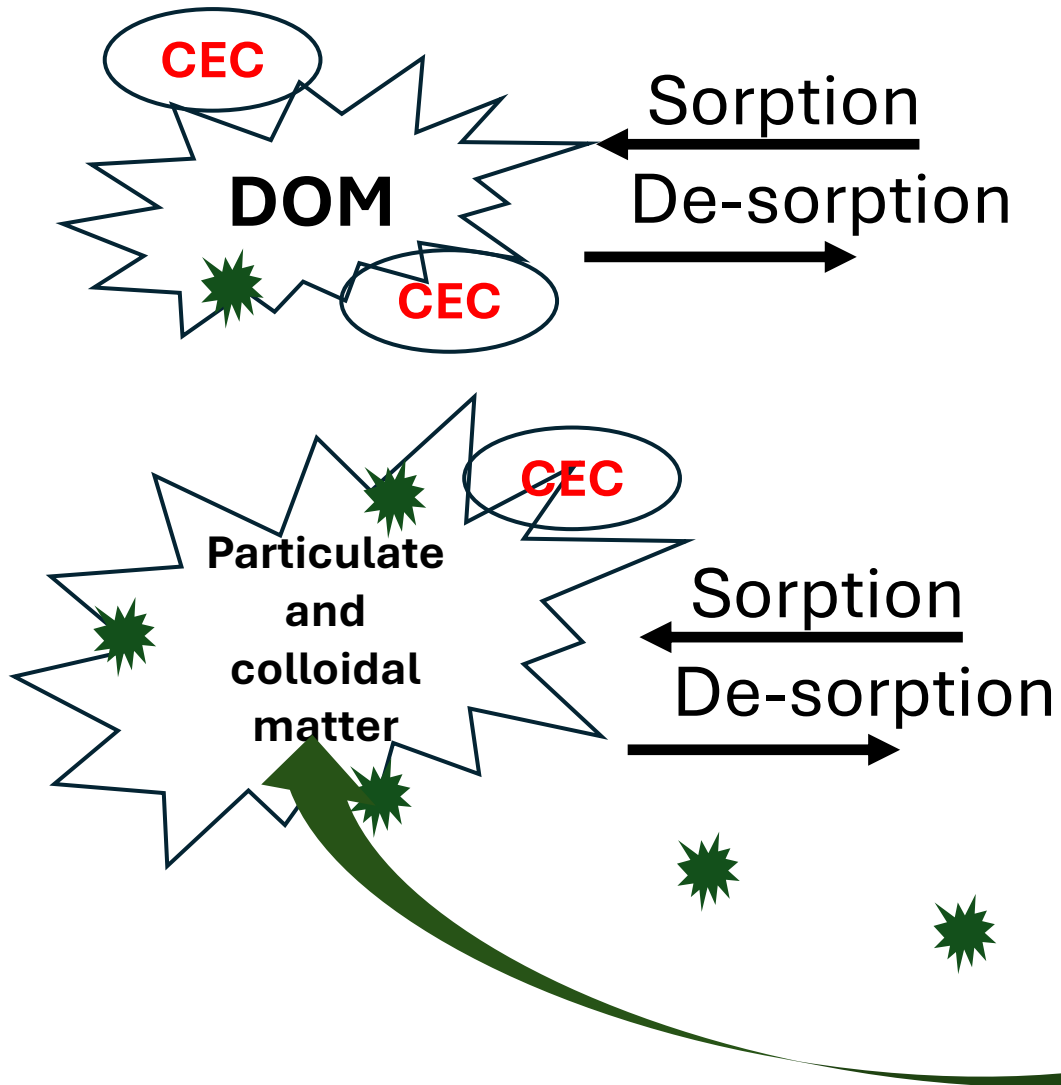
>90,000 commercially
available chemicals
(2,000 added annually)

The ultimate goal of wastewater treatment is to disassemble all the complex compound PPCPs and CECs into carbon dioxide and water or at least to something beneficial or harmless to public health or the environment

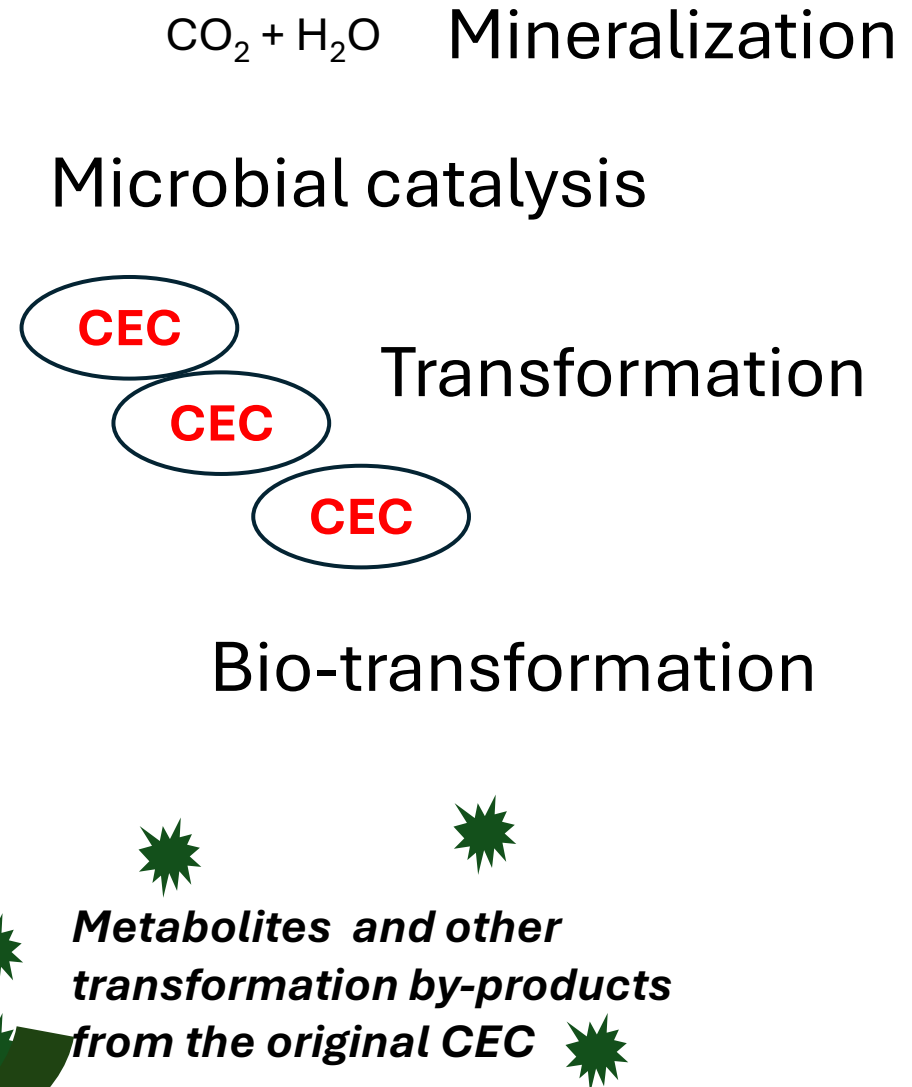


But we know that we are rarely that lucky to have this happen.

NOT SO SIMPLE



BIOAVAILABILITY



MASSTC

The Massachusetts Alternative
Septic System Test Center



A whirlwind summary of the results
from early studies at the Test Center

Two shallow-placed systems investigated

DRIP DISPERSAL



3 year study
2010-2012



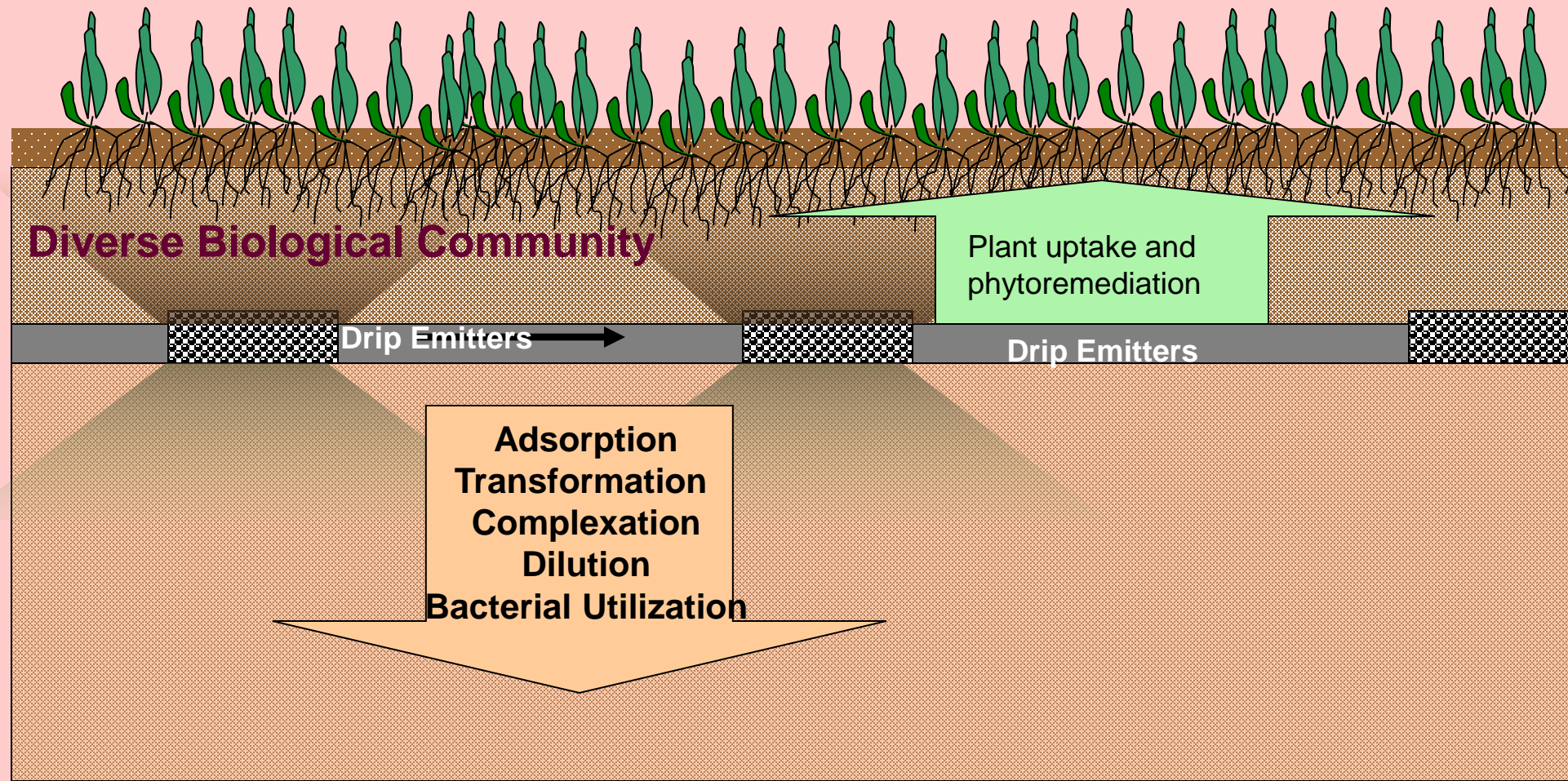
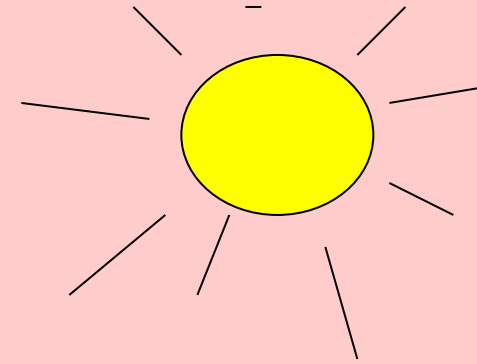
SHALLOW DRAINFIELD



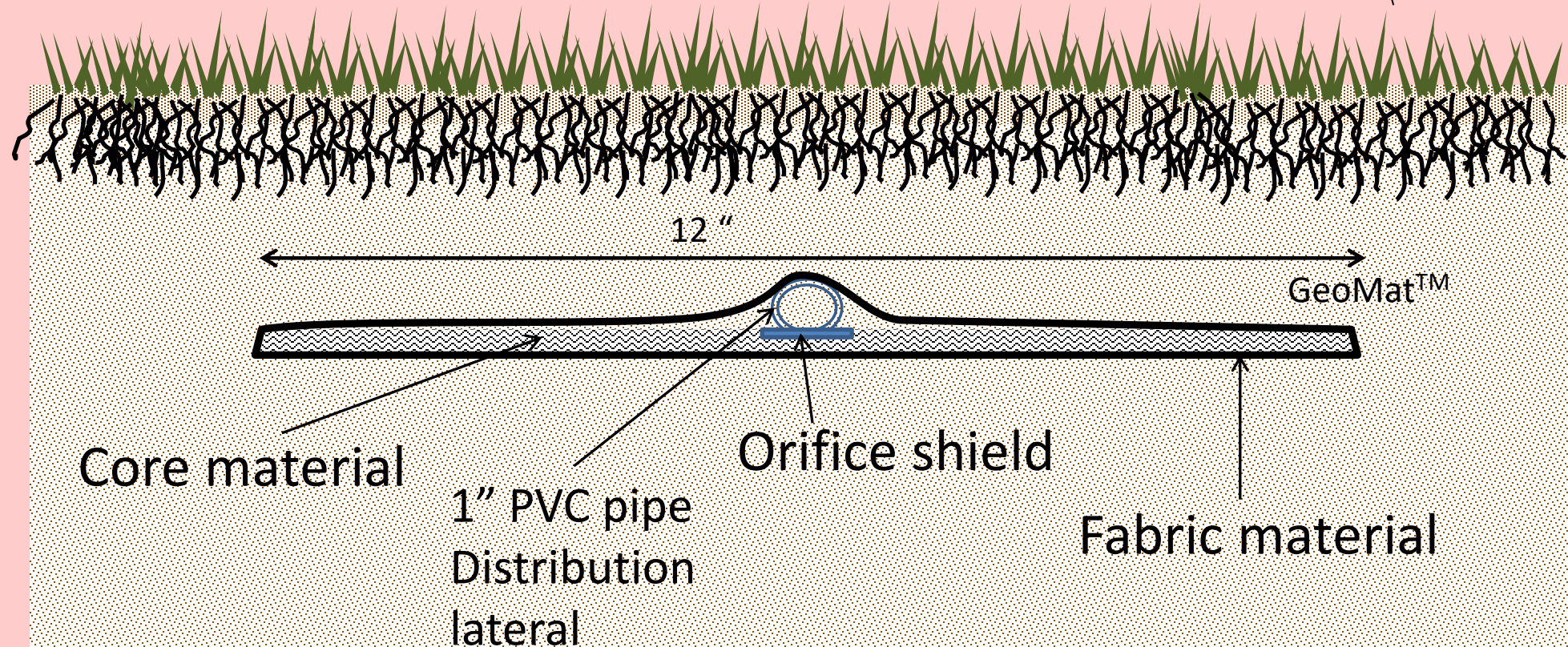
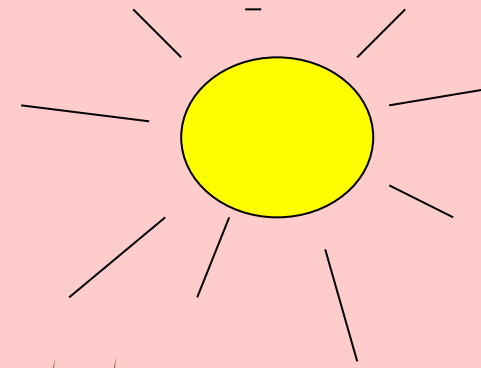
3 year study
2011-2013



Drip Dispersal Systems



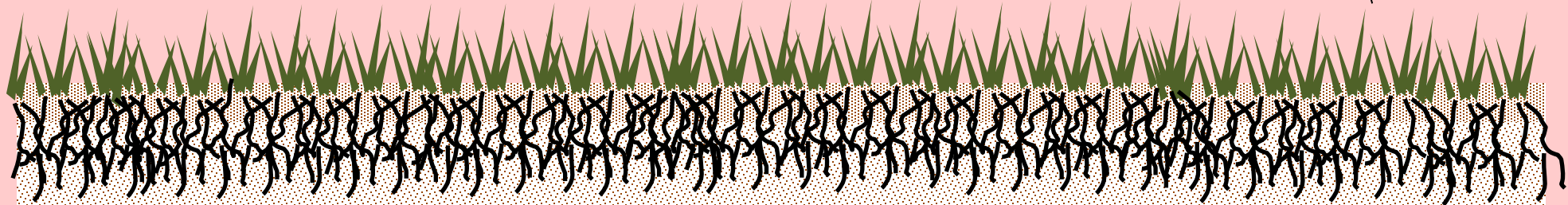
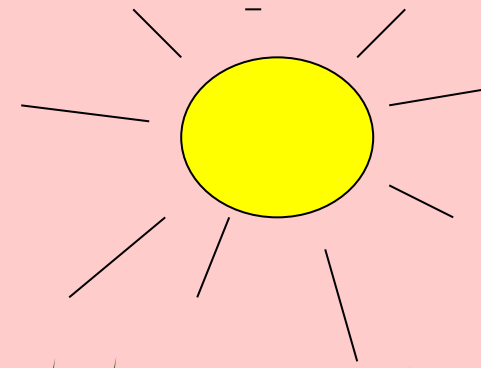
Shallow Drainfield Systems



Cross section

Shallow Drainfield Systems

(alternative installation)



1" PVC pipe
Distribution
lateral

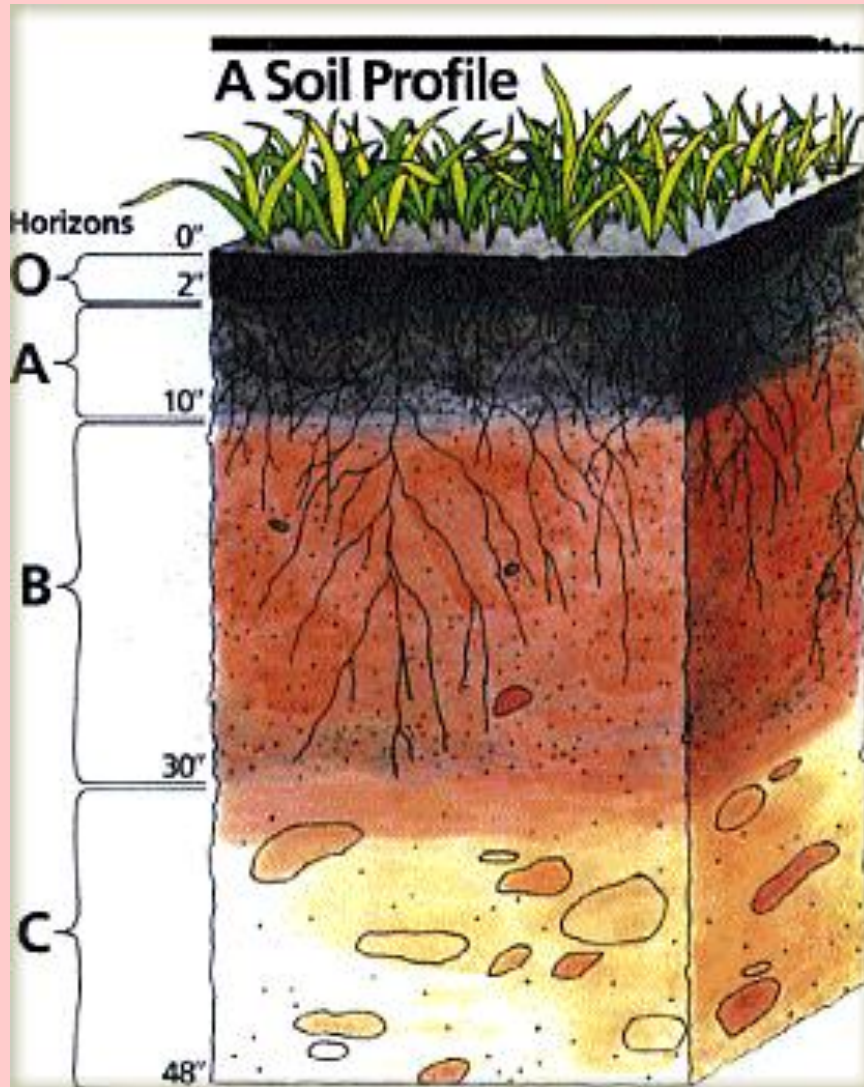
12" diameter
PVC pipe cut
lengthwise

Support

12"

Cross section

Bacteria (and other microbes) - the real workhorses of the terrestrial ecosystems



Bacteria/gram of soil

Billions

7-8 million

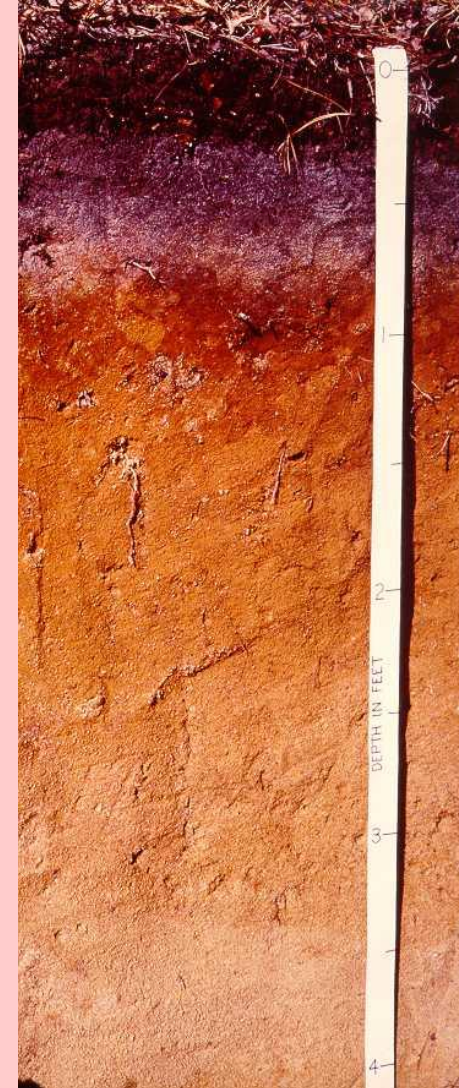
1- 2 million

400 – 500 thousand

~ 10 thousand

one thousand

hundreds



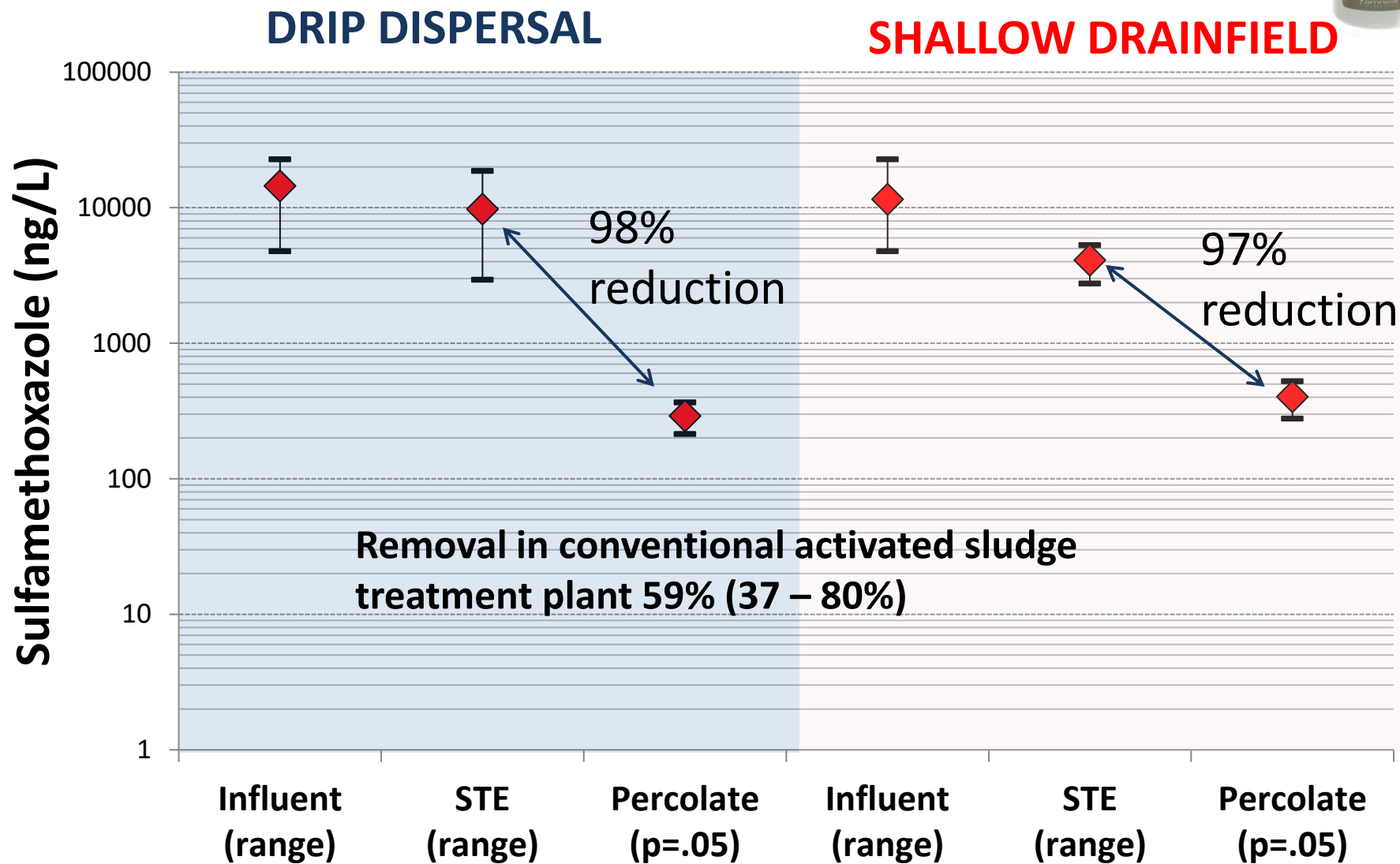


It was estimated that to cover all the compounds examined in detail at MASSTC and the relevant literature, this lecture would be over on June 21, 2025

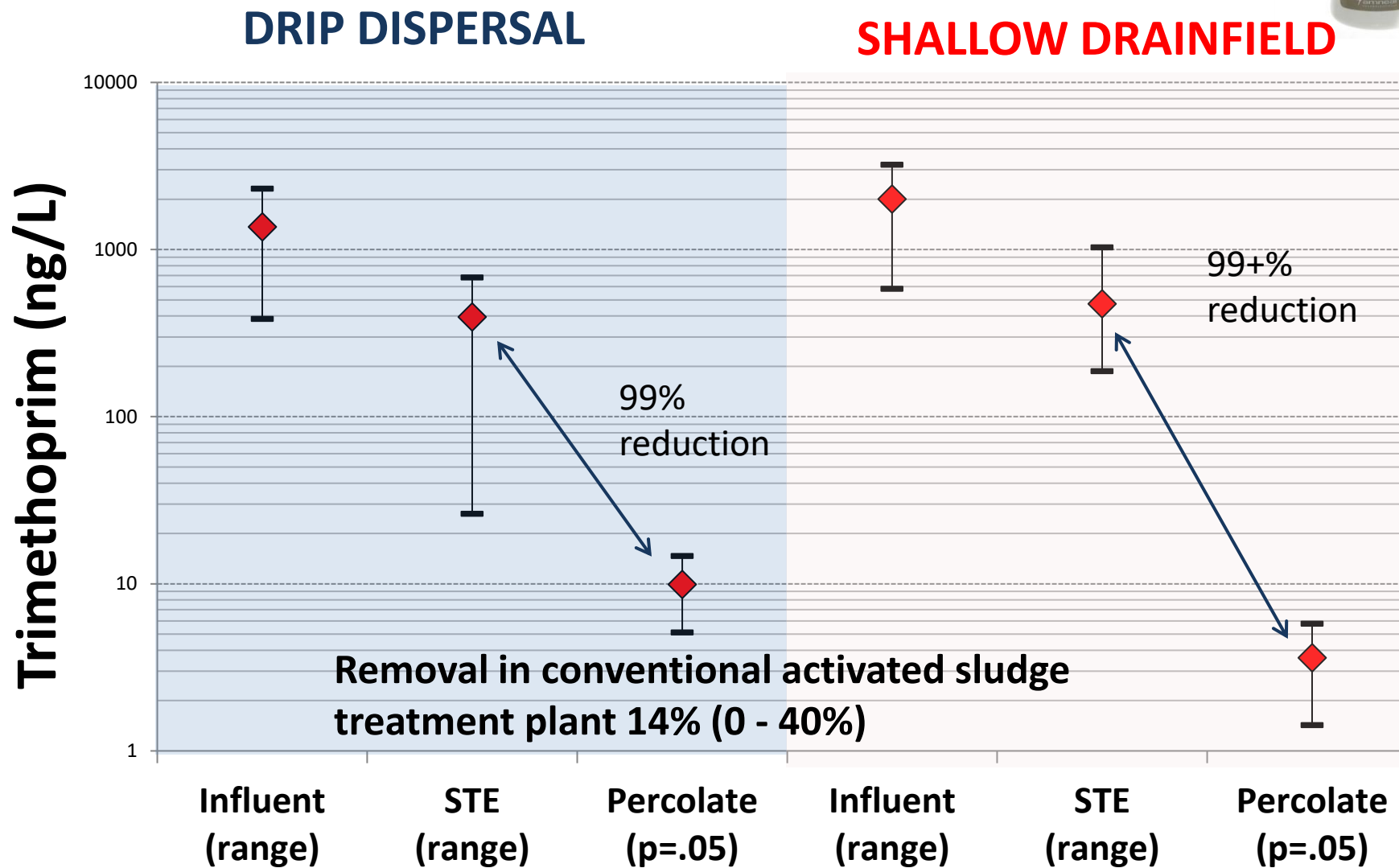
Just to mention a few



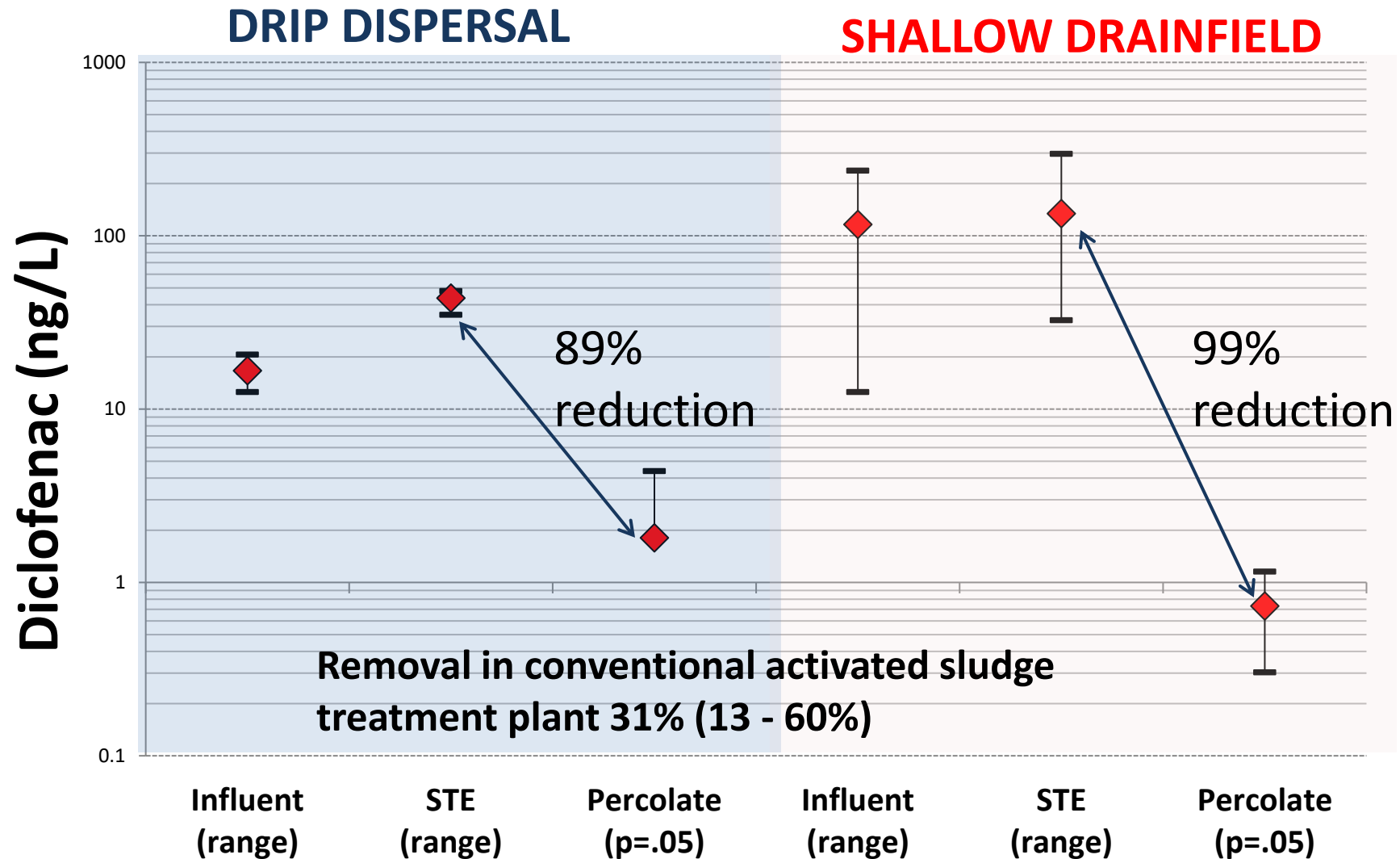
Antibiotics



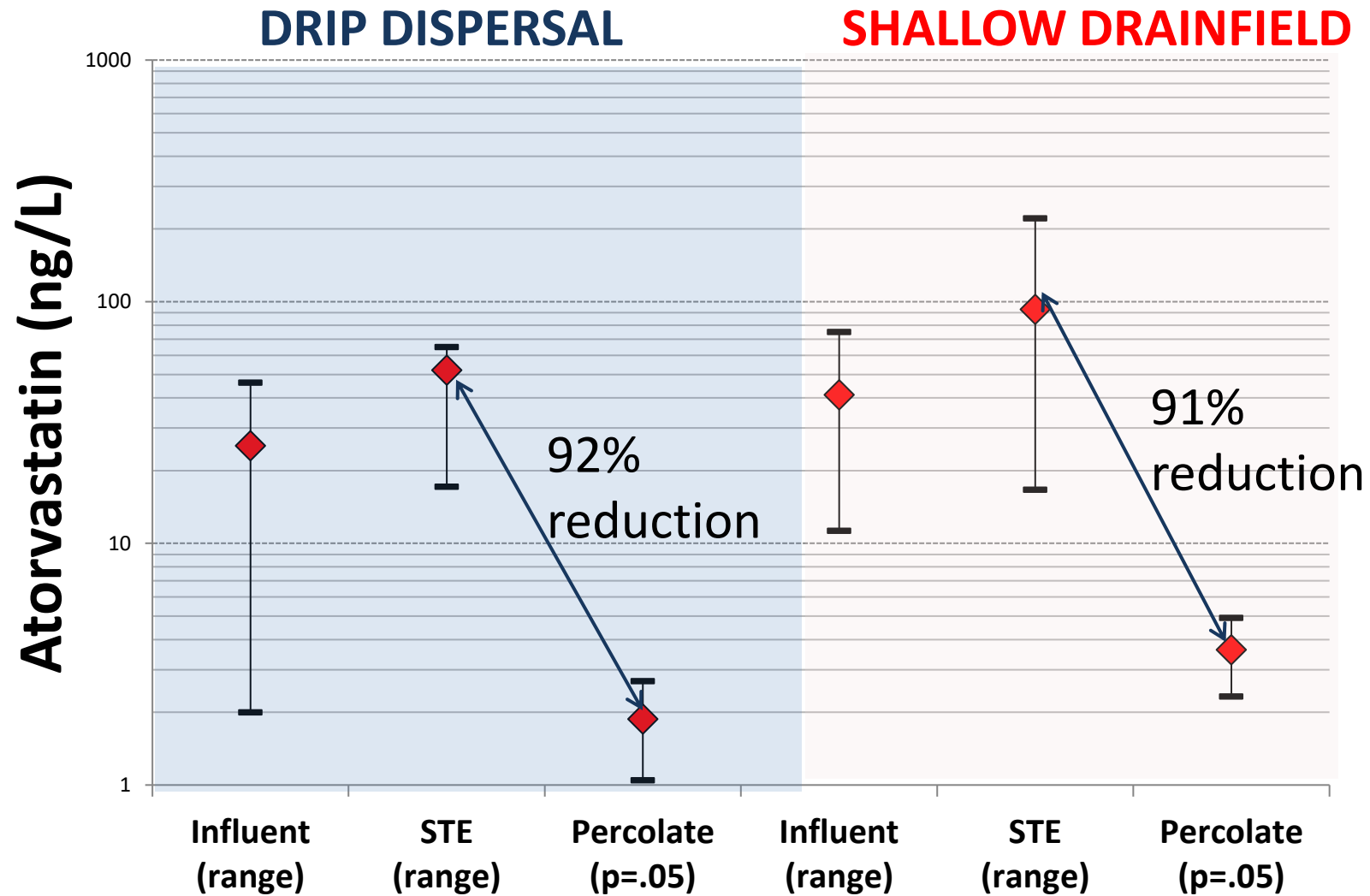
Antibiotics

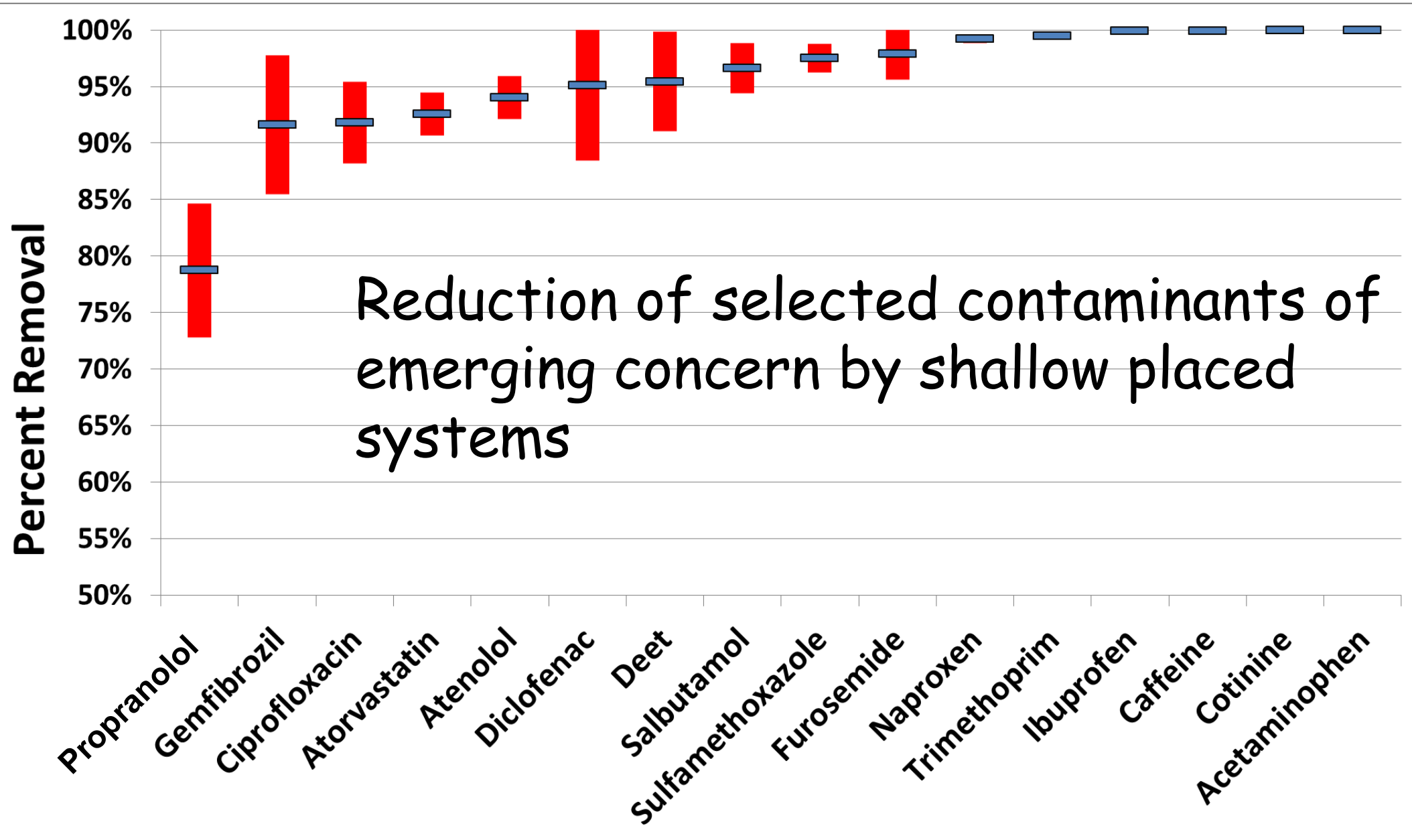


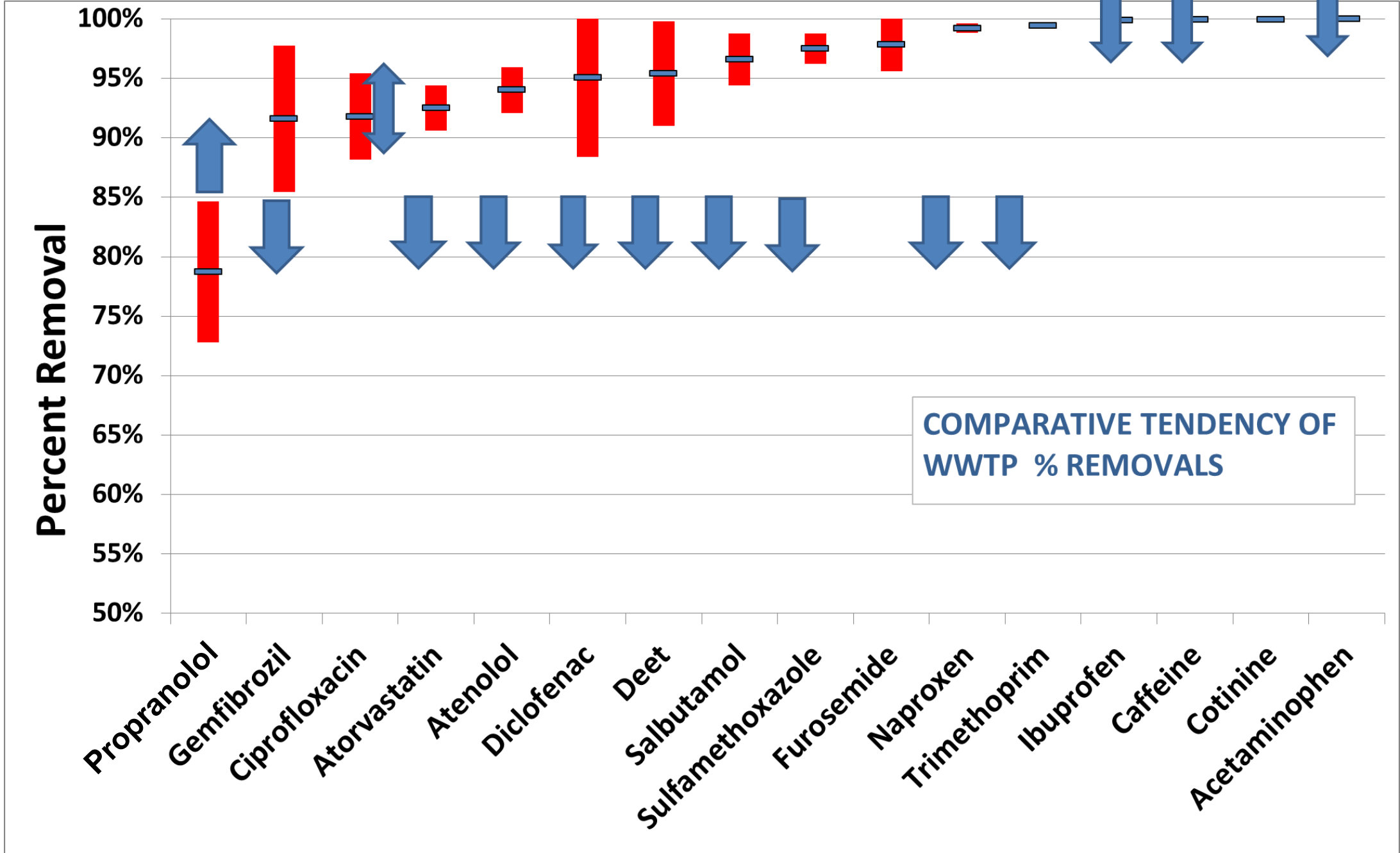
Nonsteroidal anti-inflammatory drugs



Lipid regulating drugs







Compound	Drip	Shallow Drainfield	Conventional activated sludge treatment
Acetaminophen	99.99%	99.82%	> 90% - 99.9% (b)
Atenolol	93.62%	99.03%	5.5% (2-20%)(a)
Atorvastatin	92.60%	91.18%	85-95% (d)
Caffeine	99.97%	99.93%	94.9% (c)
Ciprofloxacin	97.96%	98.17%	72% (59-85%)(a)
DEET	98.45%	98.24%	69% (48-90%) (e)
Diclofenac	89.16%	99.37%	31% (13-60%)(a)
Furosemide	97.60%	98.40%	59.8% (c)
Ibuprofen	99.94%	99.93%	74%(44-100%)(a)
Miconazole	0.00%	0.00%	
Naproxen	99.50%	96.80%	75% (59-92%)(a)
Propranolol	71.20%	96.89%	96% (a)
Sulfamethoxazole	97.90%	96.50%	59% (37-80%)(a)
TCEP	0.00%	0.00%	
Trimethoprim	99.20%	99.80%	14% (0 - 40%)(a)

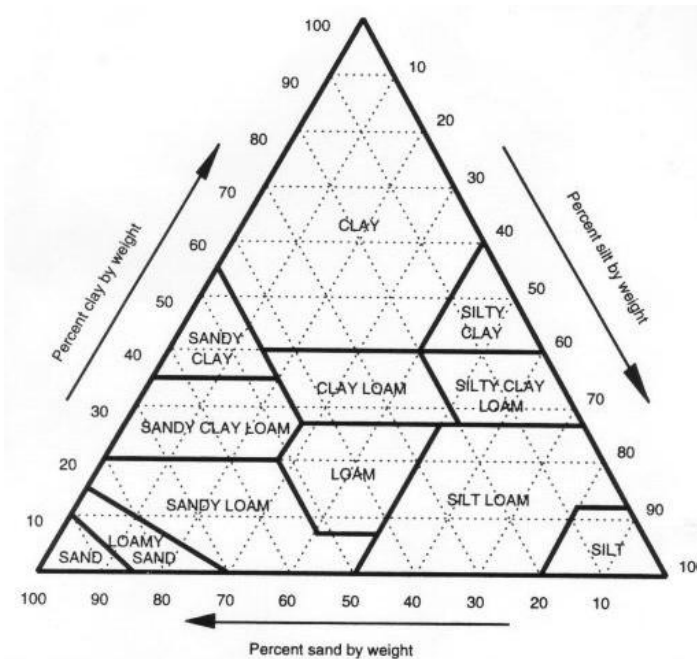
Projects to investigate whether there are design changes that can enhance the ability of septic systems to remove emerging contaminants.



**MASSACHUSETTS ALTERNATIVE
SEPTIC SYSTEM TEST CENTER**

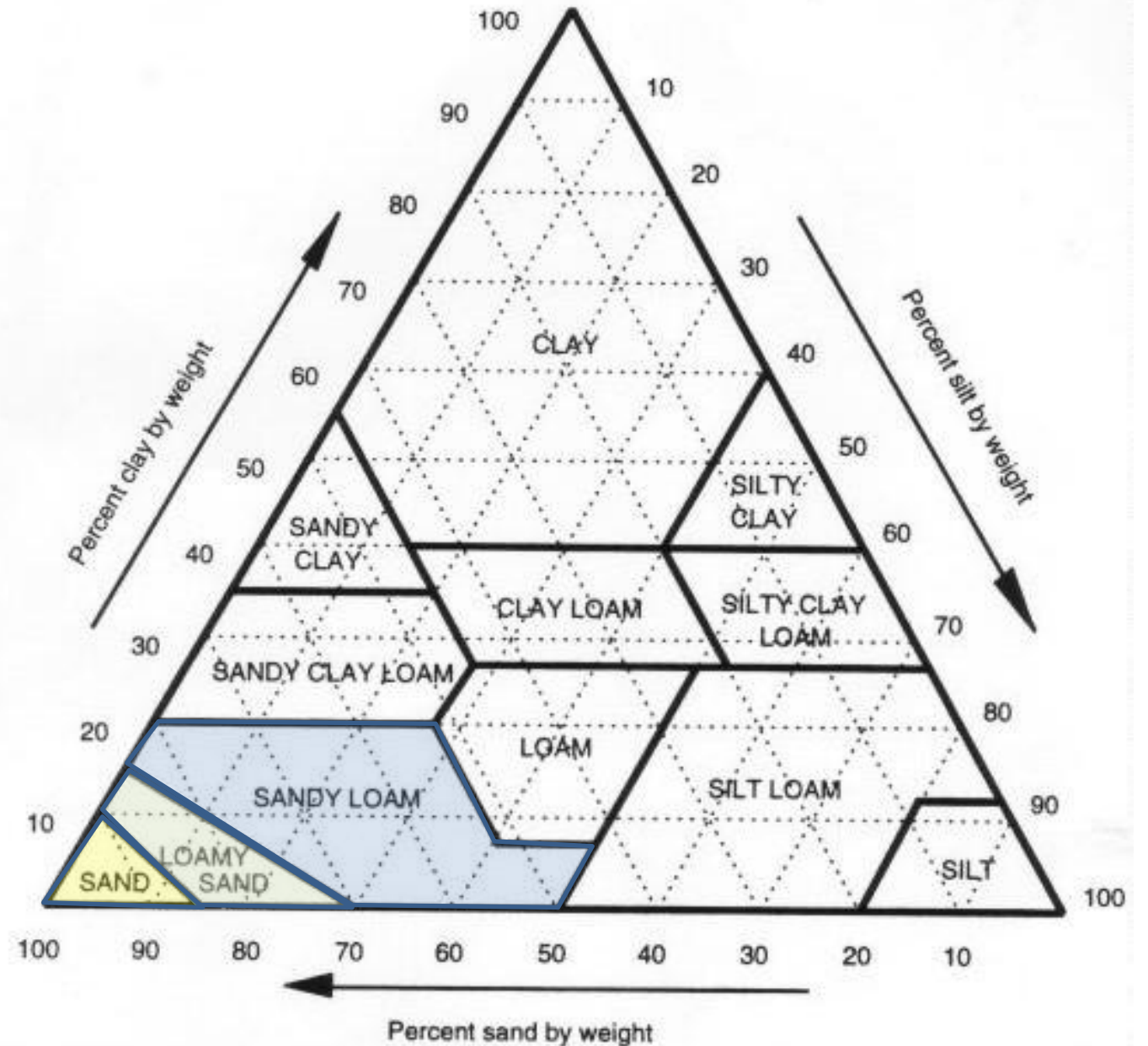
A large, rectangular, light-colored sign with bold, black, sans-serif lettering. The sign is supported by two wooden posts and is situated in a grassy field. In the background, a chain-link fence runs diagonally across the frame, with trees and a few parked cars visible beyond it. The sky is blue with scattered white clouds.

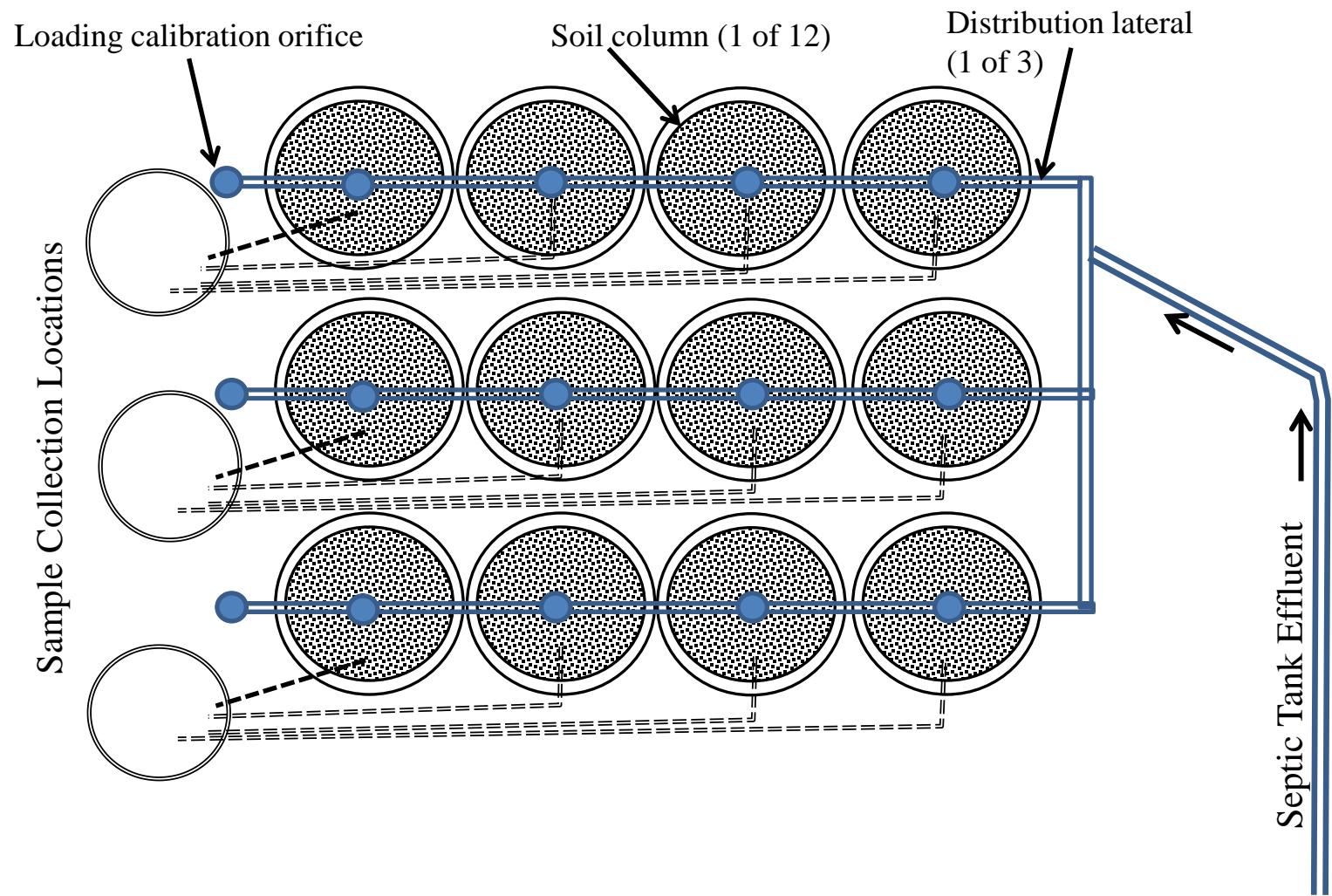
The Effect of Three Soil Types the Removal of Selected Micro-Constituents and Contaminants of Emerging Concern

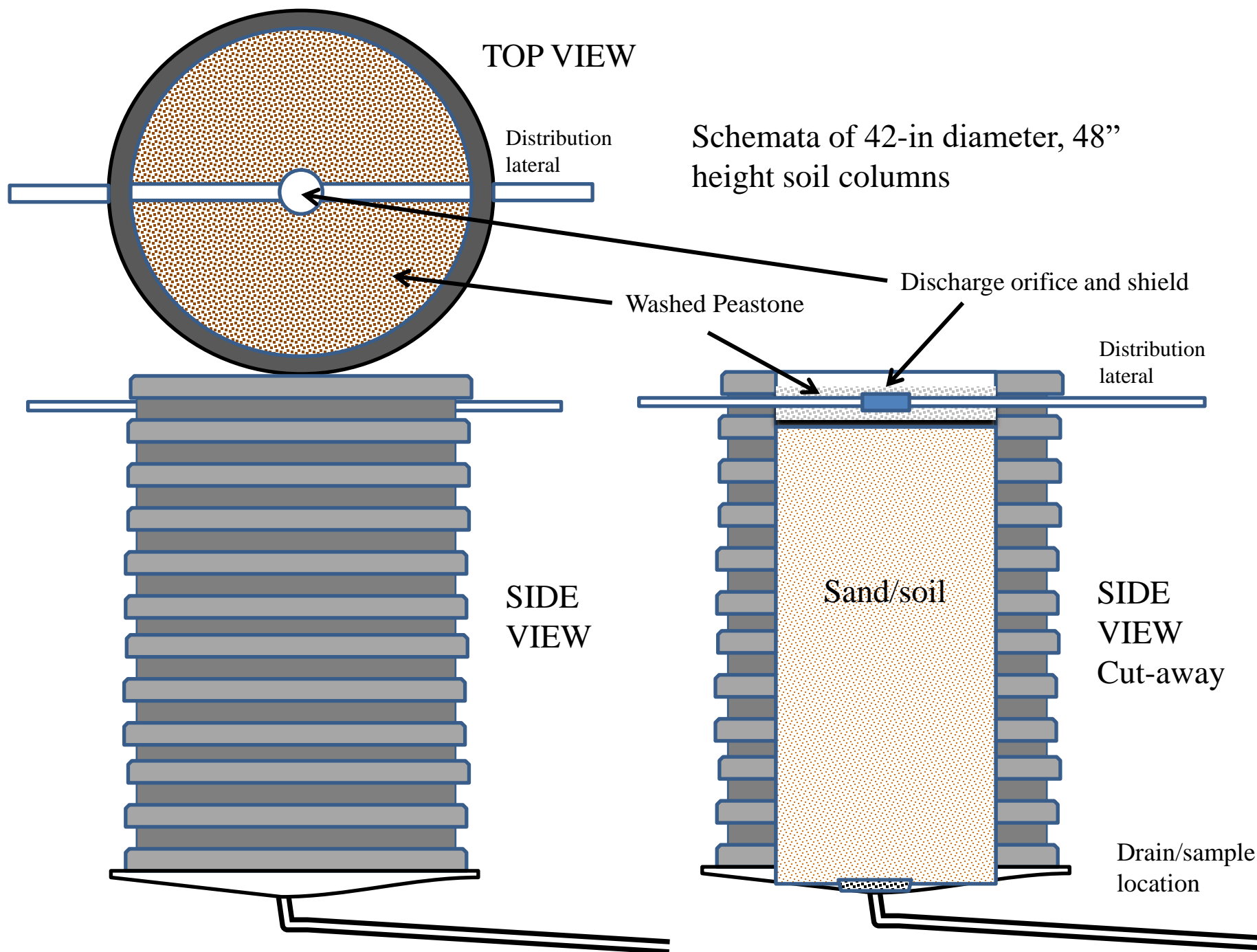


This project was funded by the Massachusetts Department of Environmental Protection with additional funds from the United States Environmental Protection Agency under a Section 319 competitive grant. The contents of this report do not necessarily reflect the views or policies of the departments mentioned nor does the mention of any product trade name constitute an endorsement.

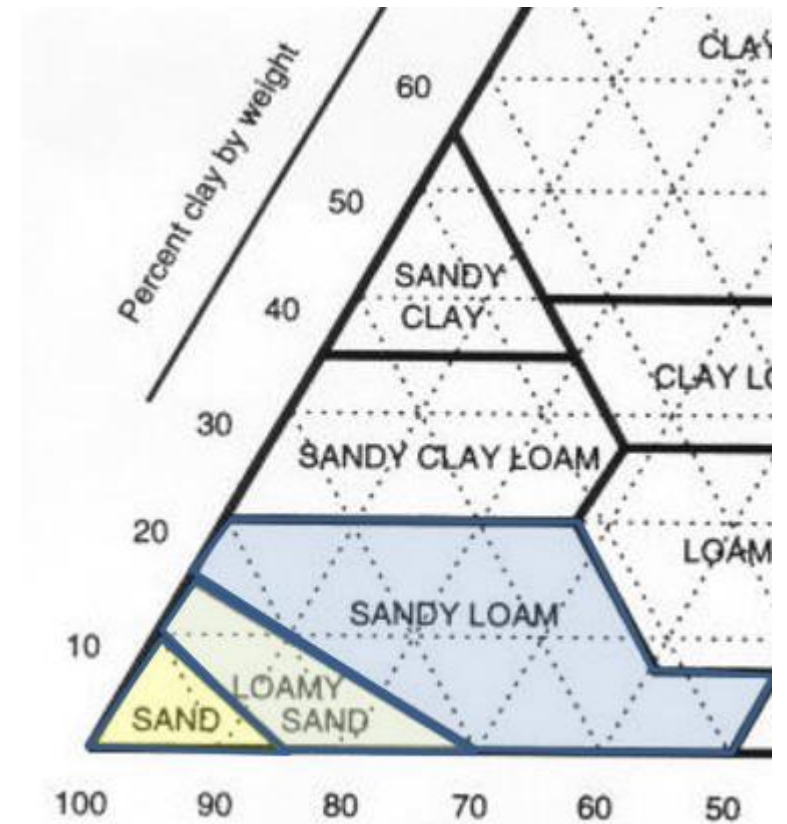
Can soil type influence the treatment for PPCPs and CECs ?

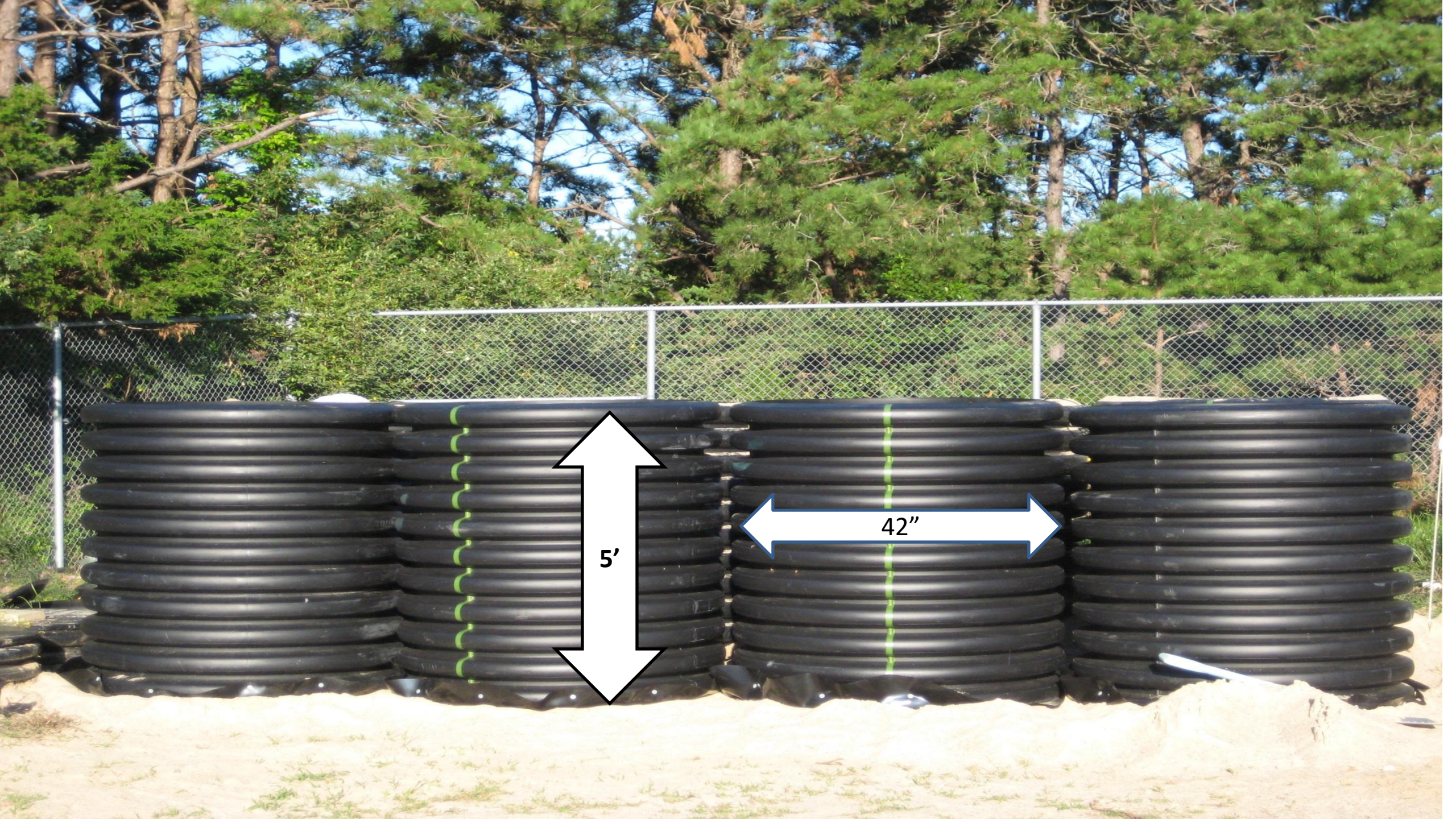






**Three soil types
and four
replicates of
each soil type**



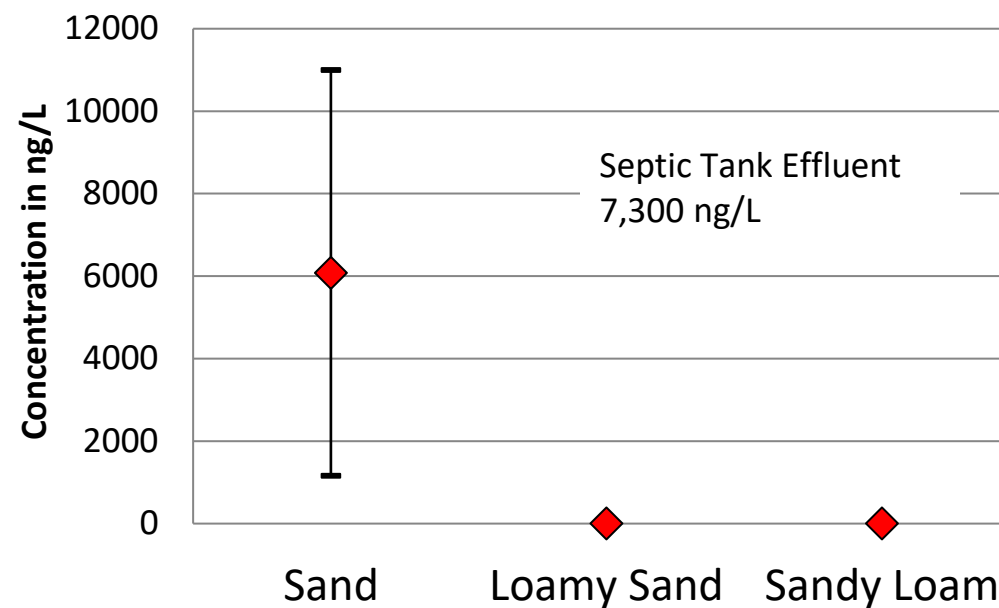


5'

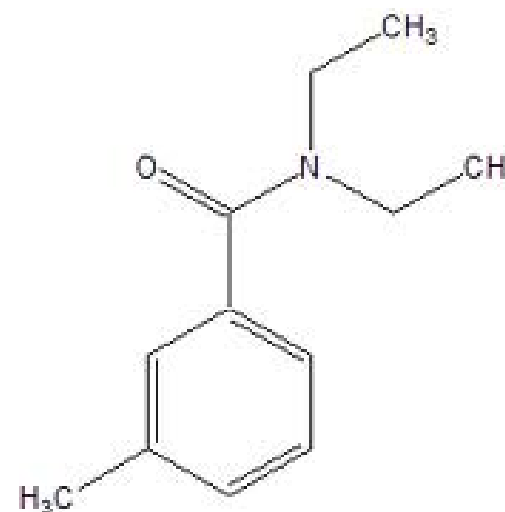
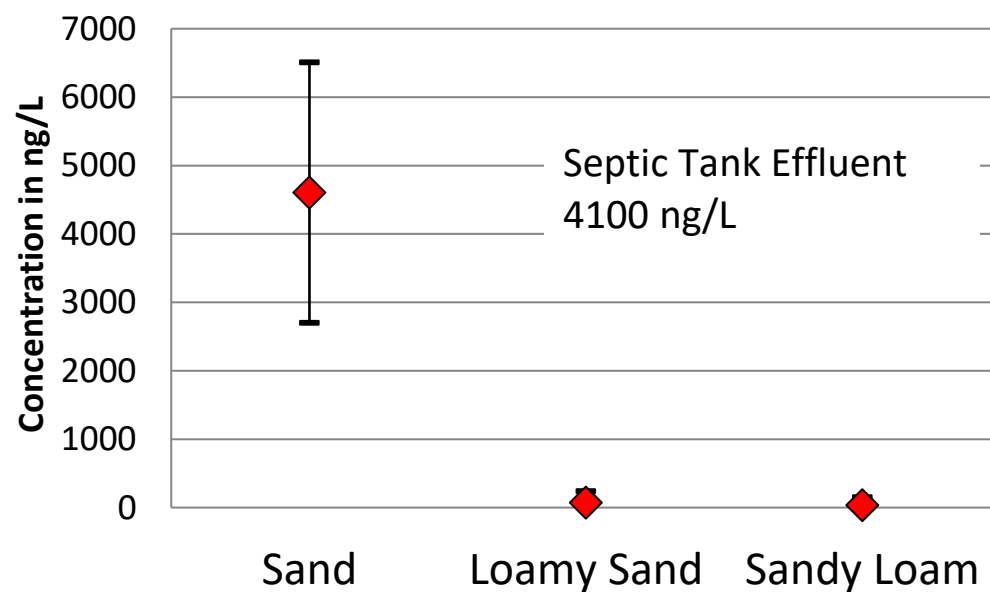
42"



DEET (May 2014)

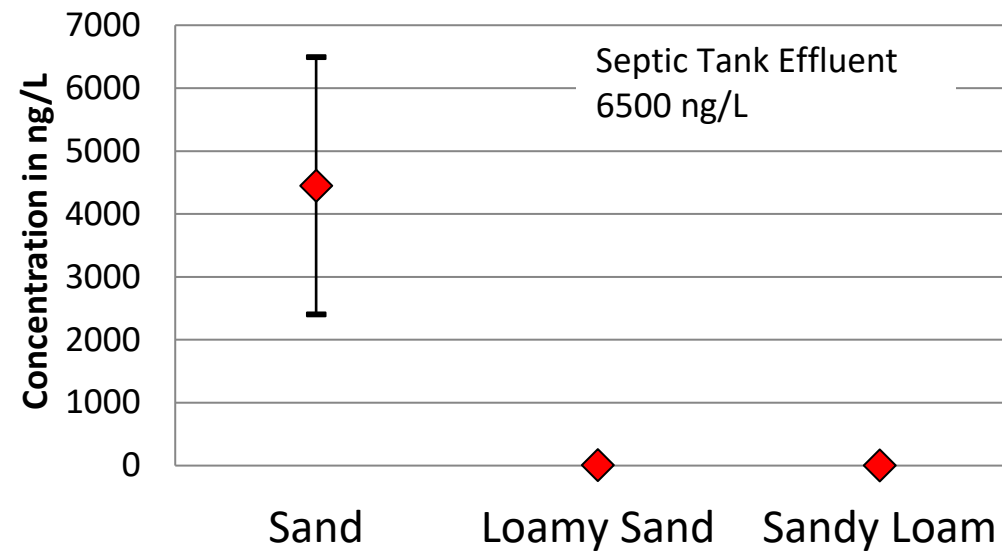


DEET (June, 2014)

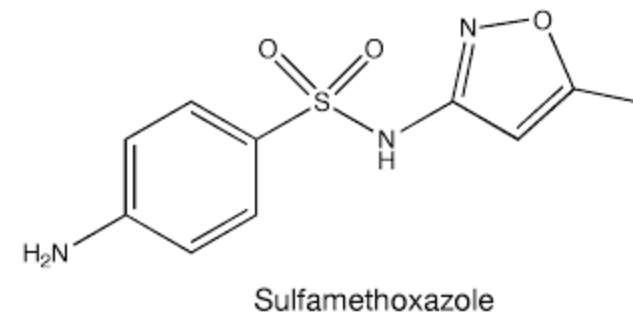
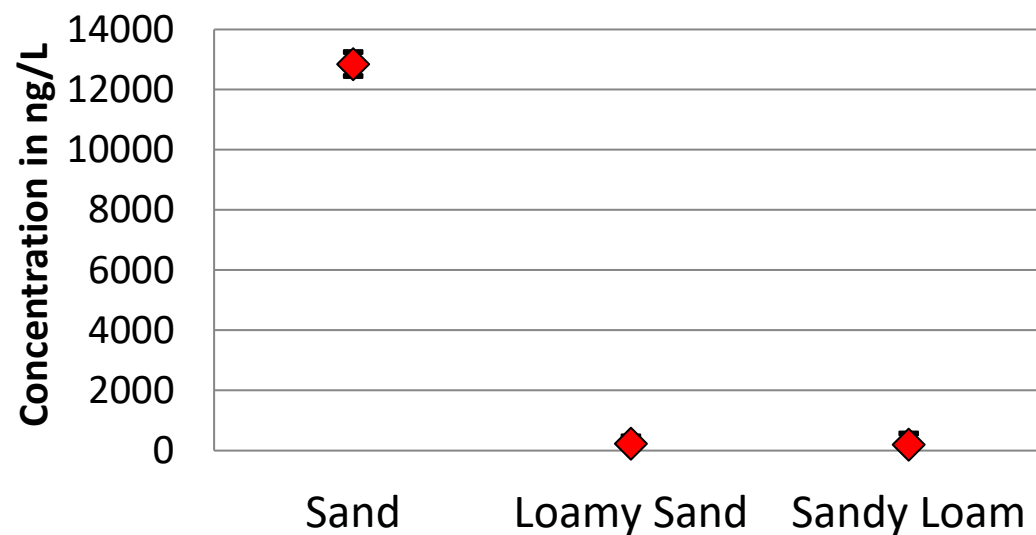




Sulfamethoxazole (May 2014)

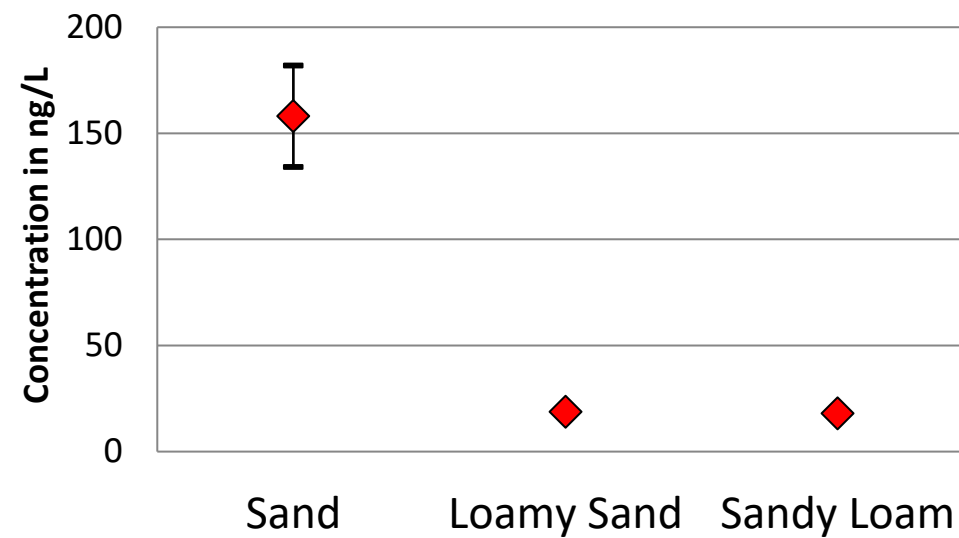


Sulfamethoxazole (June, 2014)

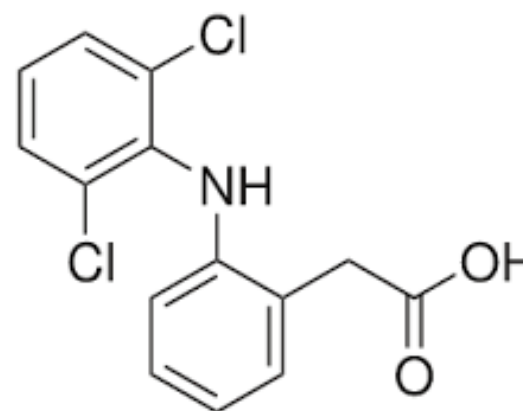
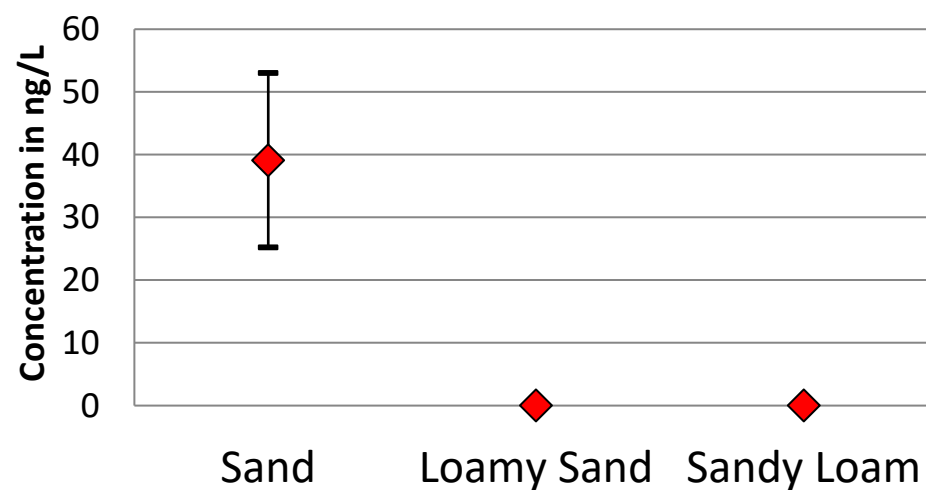




Diclofenac (May 2014)

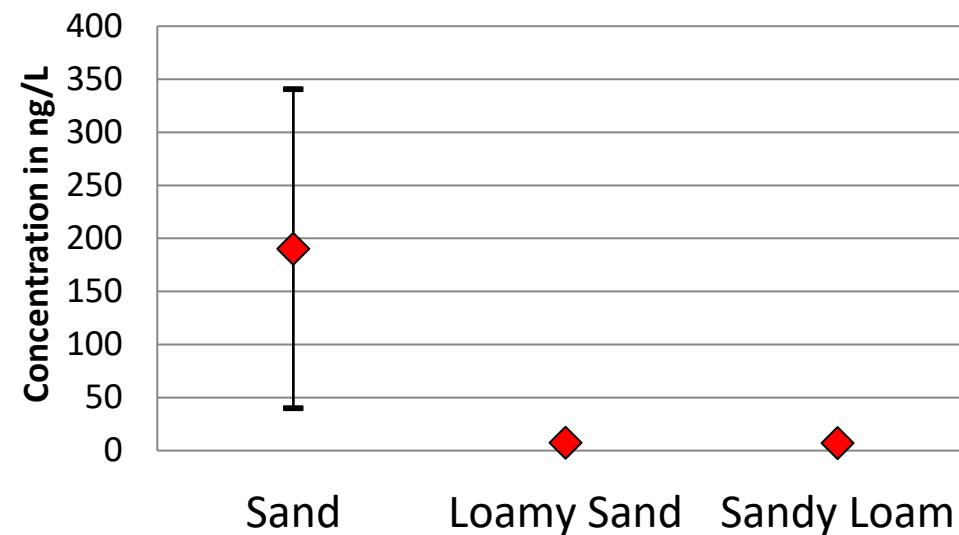


Diclofenac (June, 2014)

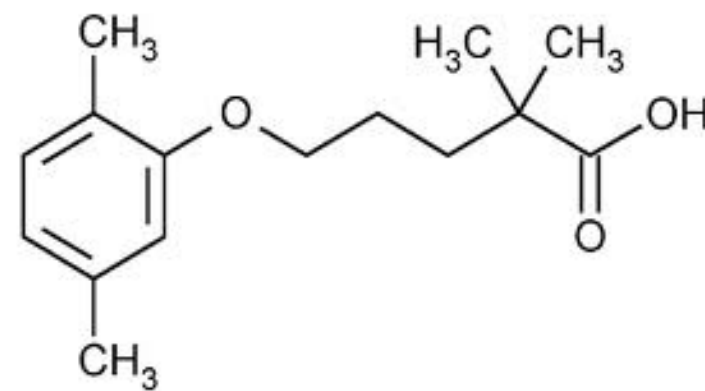
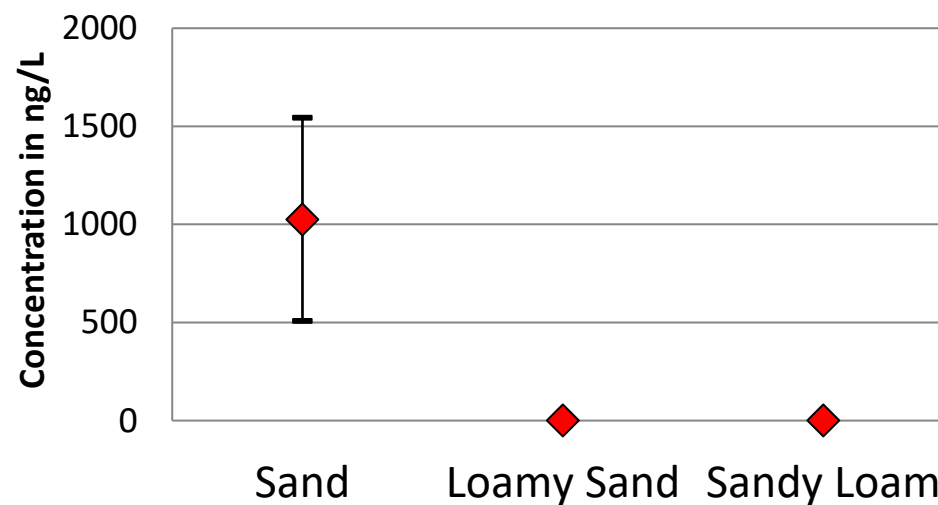




Gemfibrozil (May 2014)



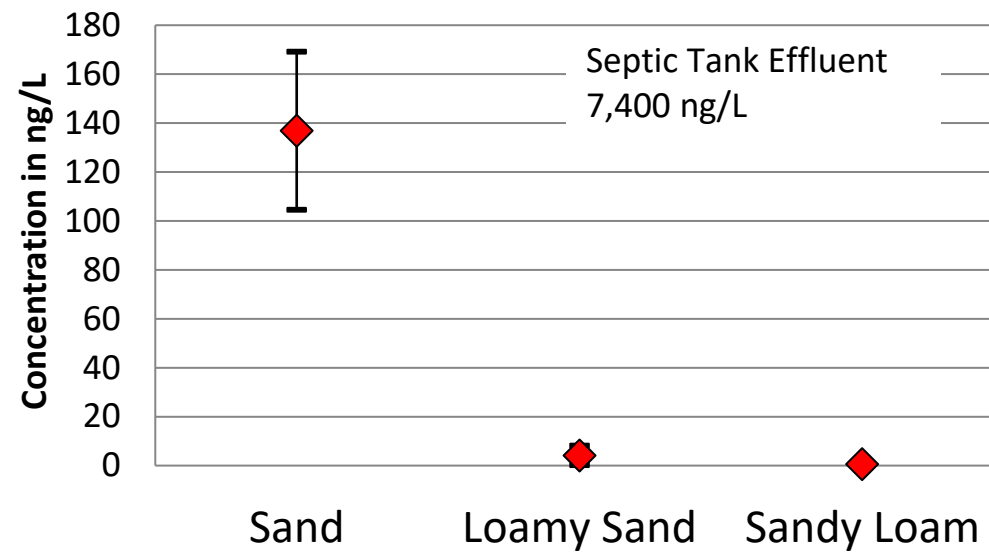
Gemfibrozil (June, 2014)



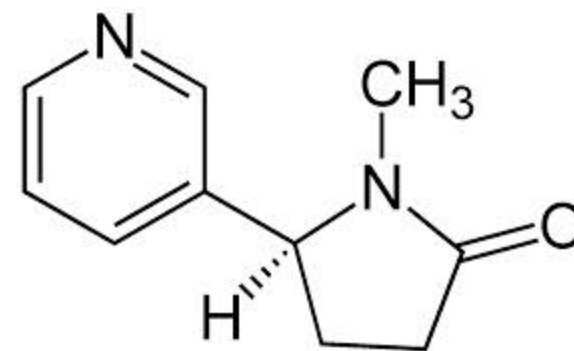
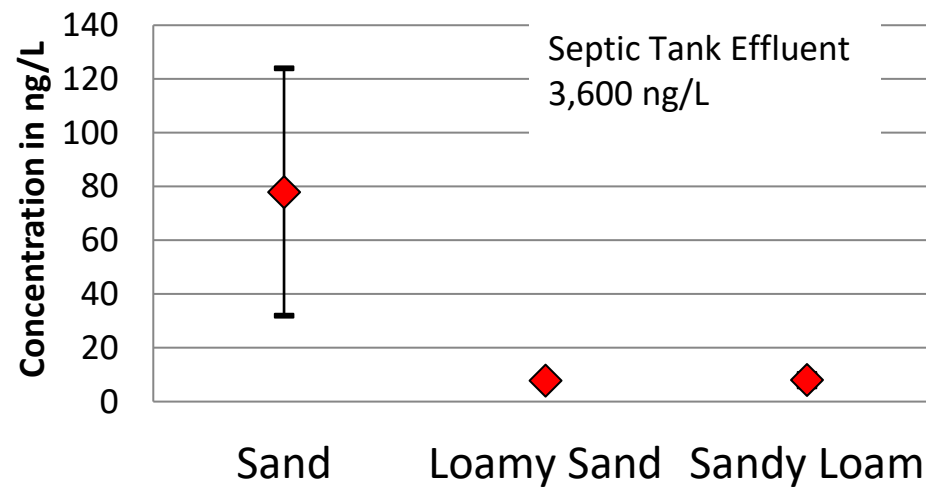
Gemfibrozil is the generic name for an oral drug used to lower lipid levels. It belongs to a group of drugs known as fibrates



Cotinine (May 2014)

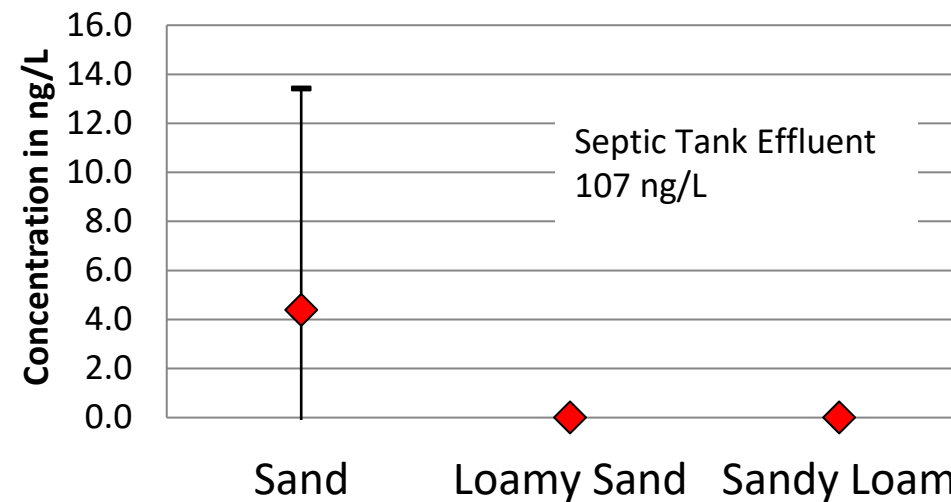


Cotinine (June, 2014)

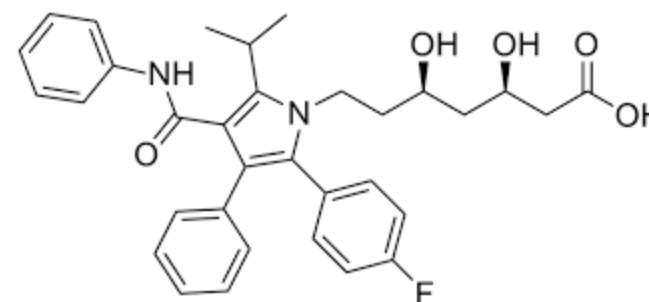
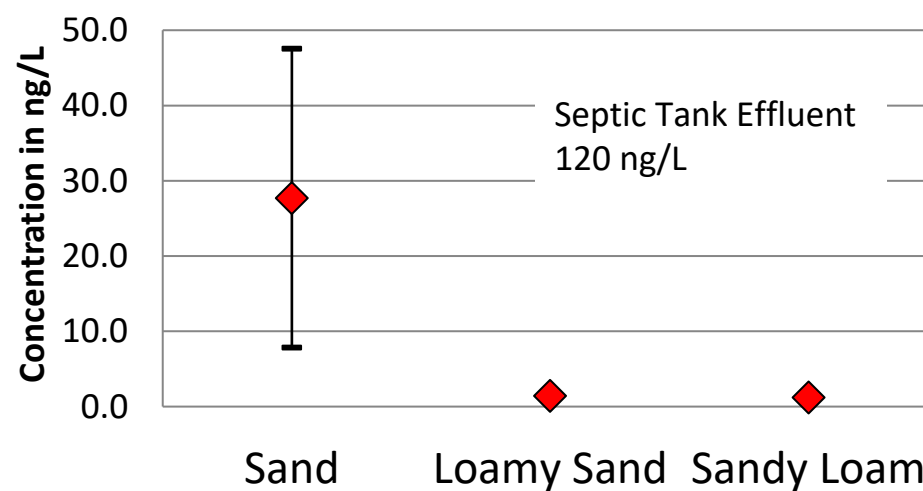




Atorvastatin (May 2014)

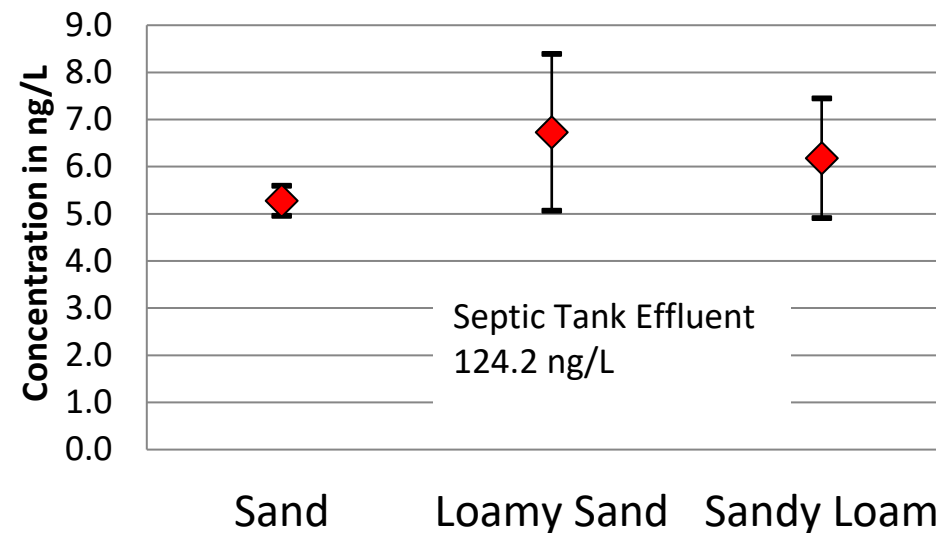


Atorvastatin (June, 2014)

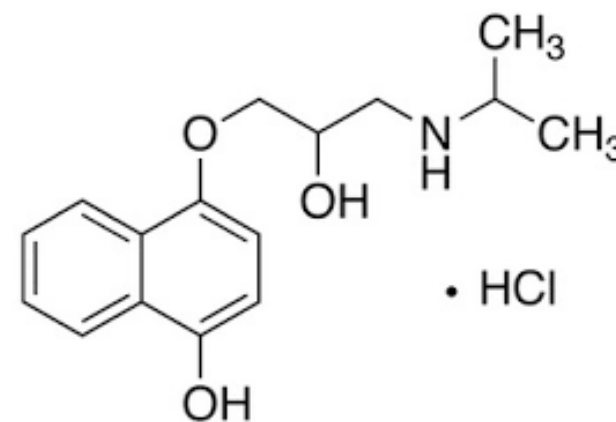
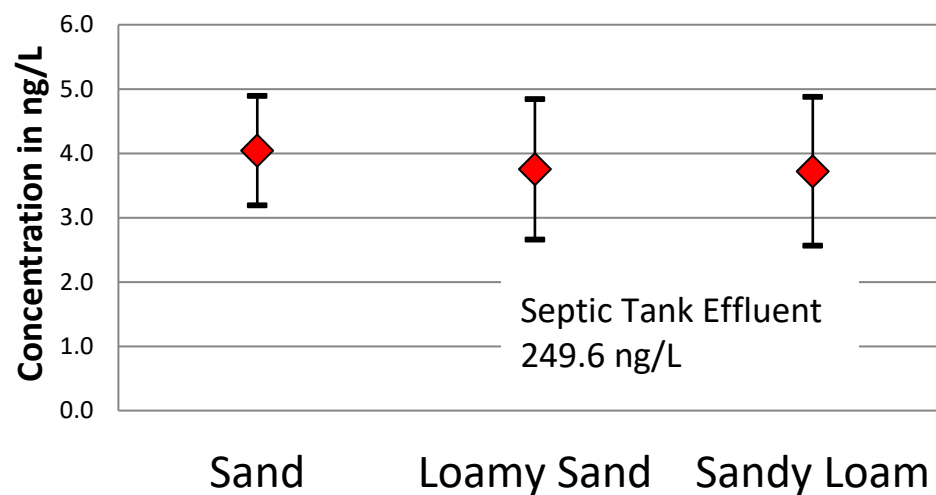




Propranolol (May 2014)

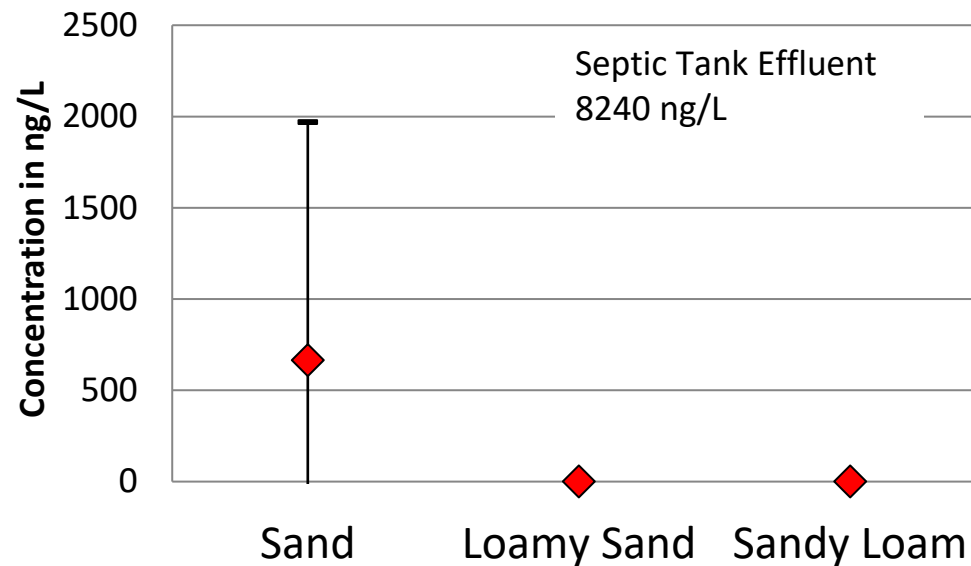


Propranolol (June, 2014)

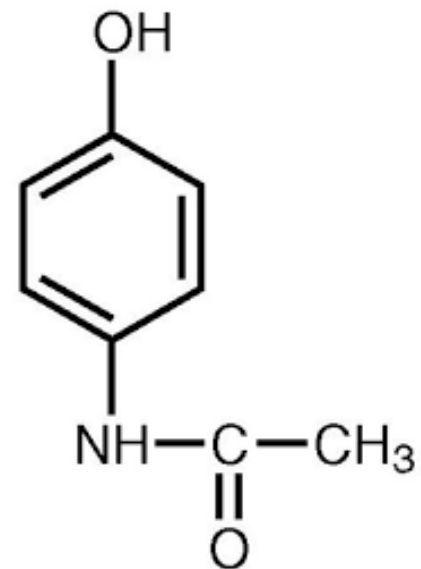
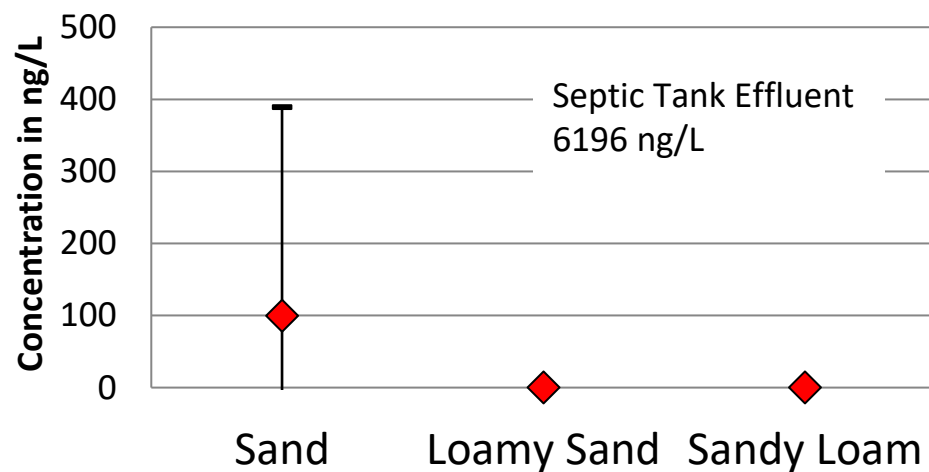




Acetaminophen (May 2014)

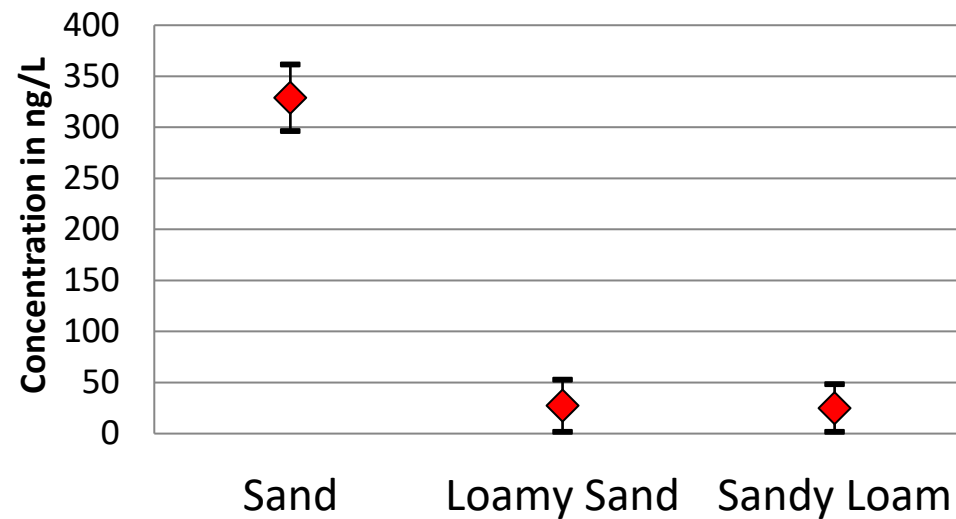


Acetaminophen (June, 2014)

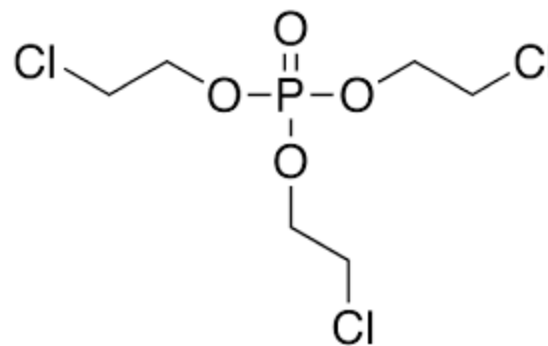
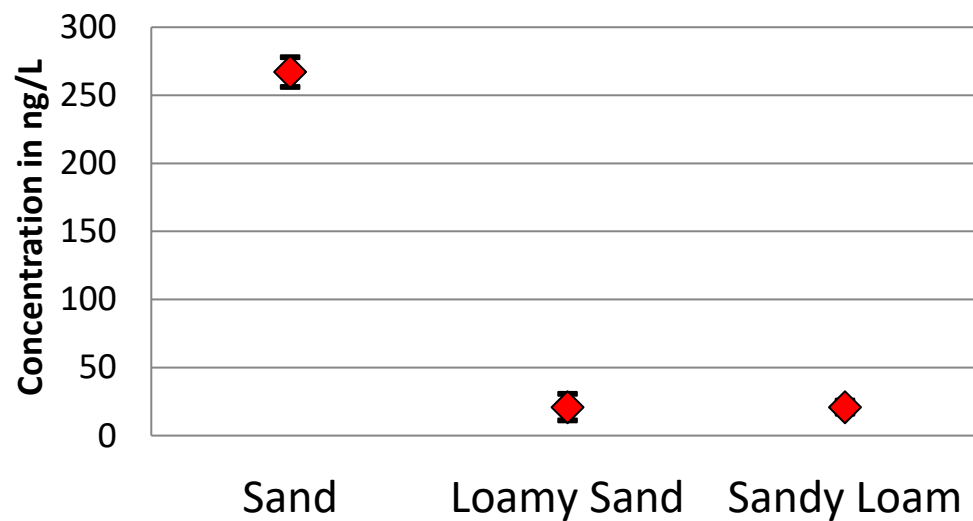




TCEP (May 2014)

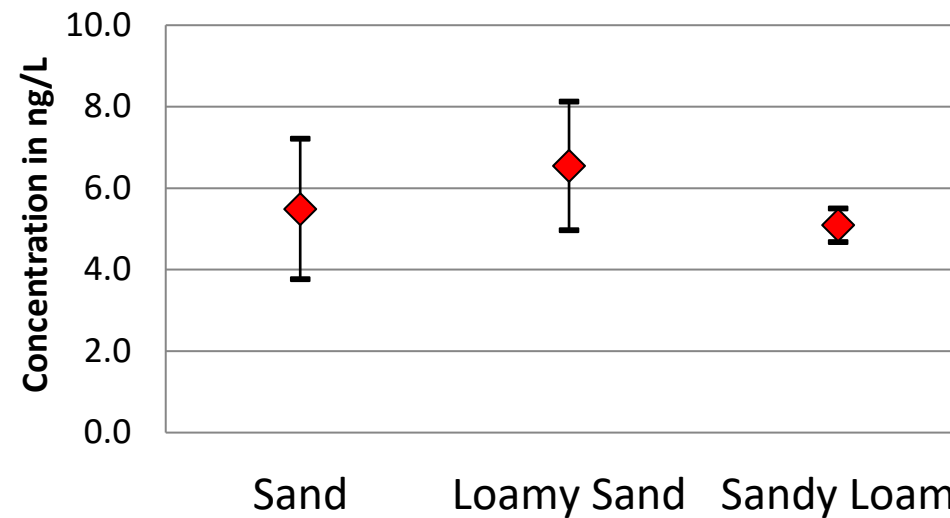


TCEP (June, 2014)

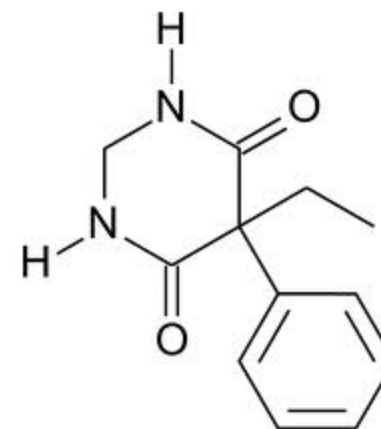
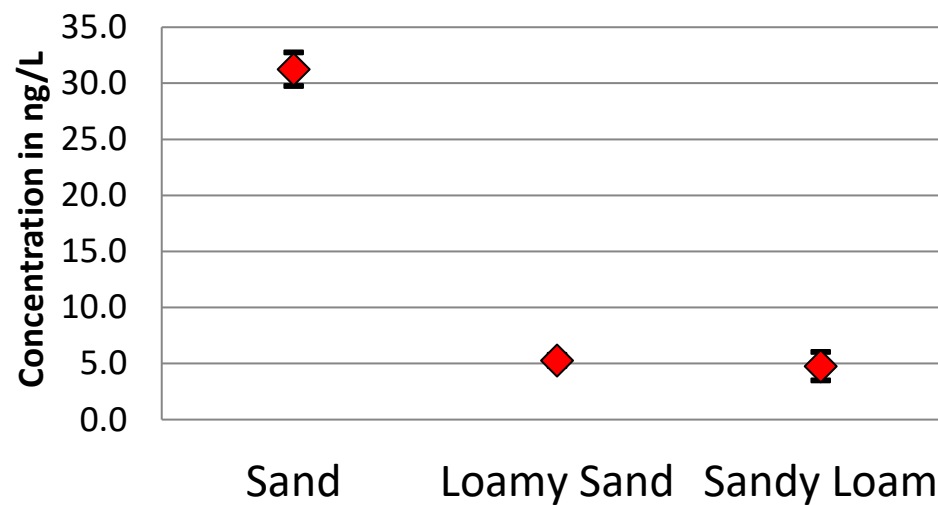




Primidone (May 2014)

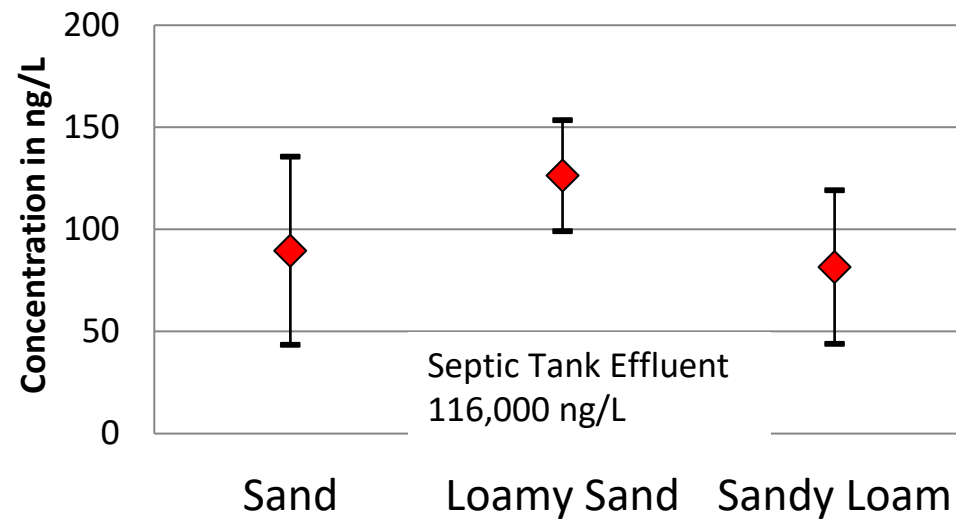


Primidone (June, 2014)

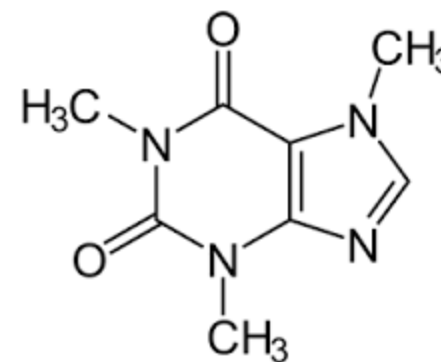
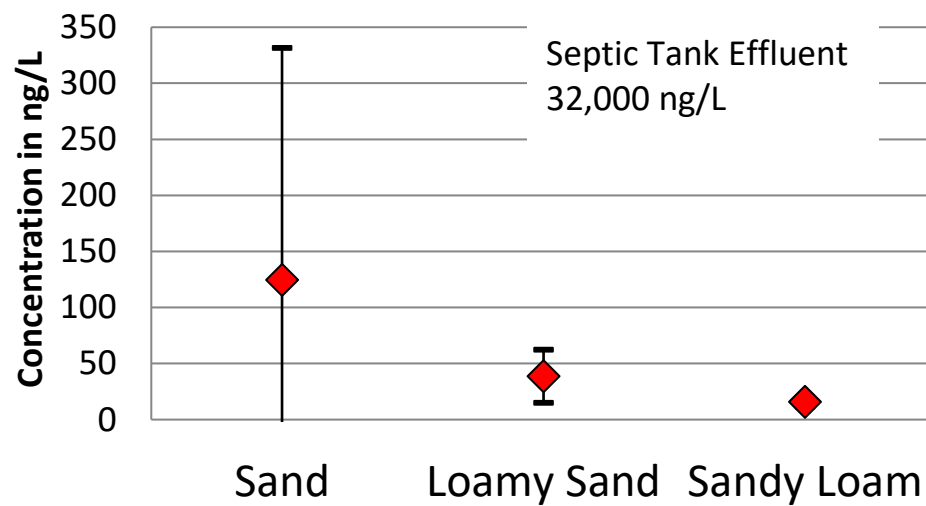




Caffeine (May 2014)

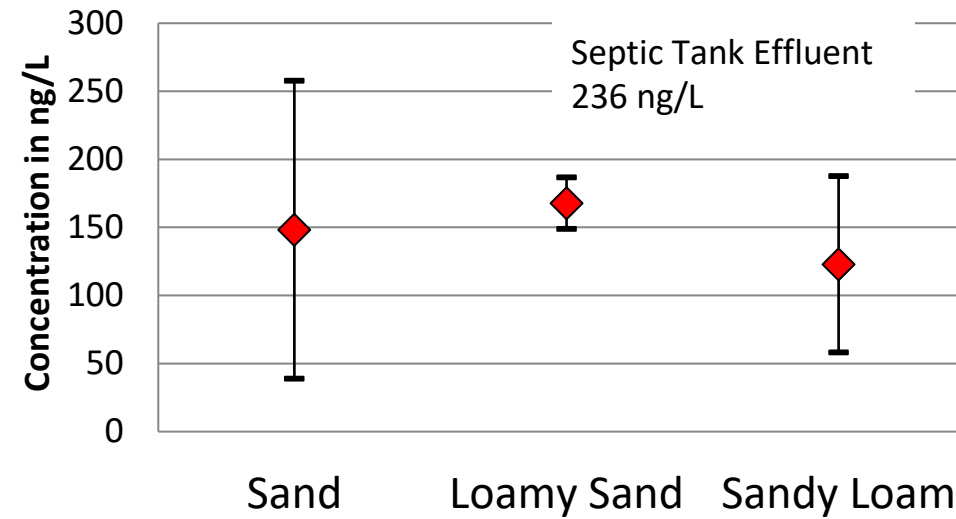


Caffeine (June, 2014)

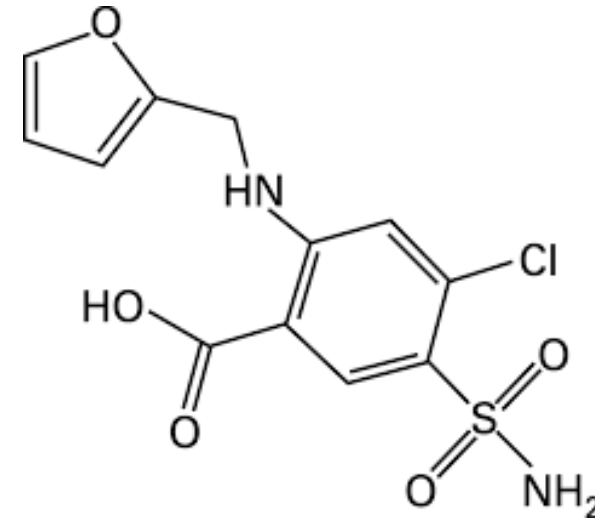
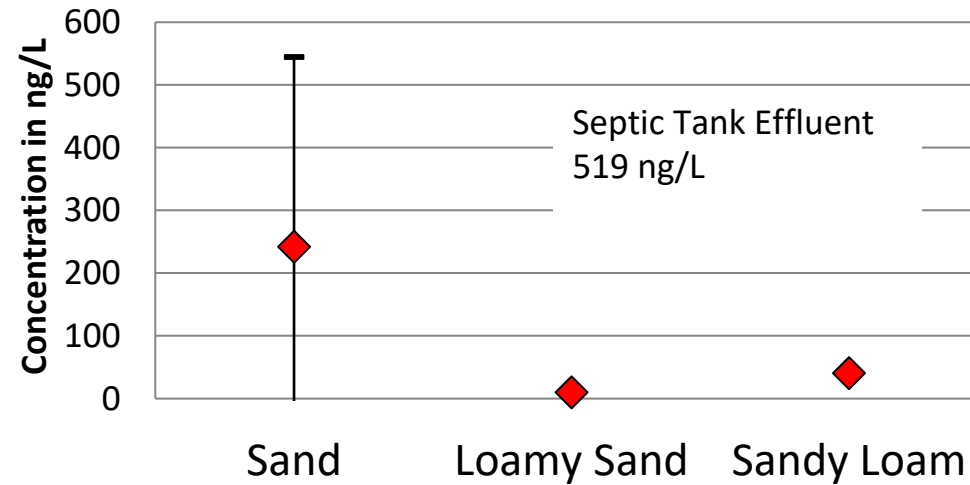




Furosemide (May 2014)



Furosemide (June, 2014)

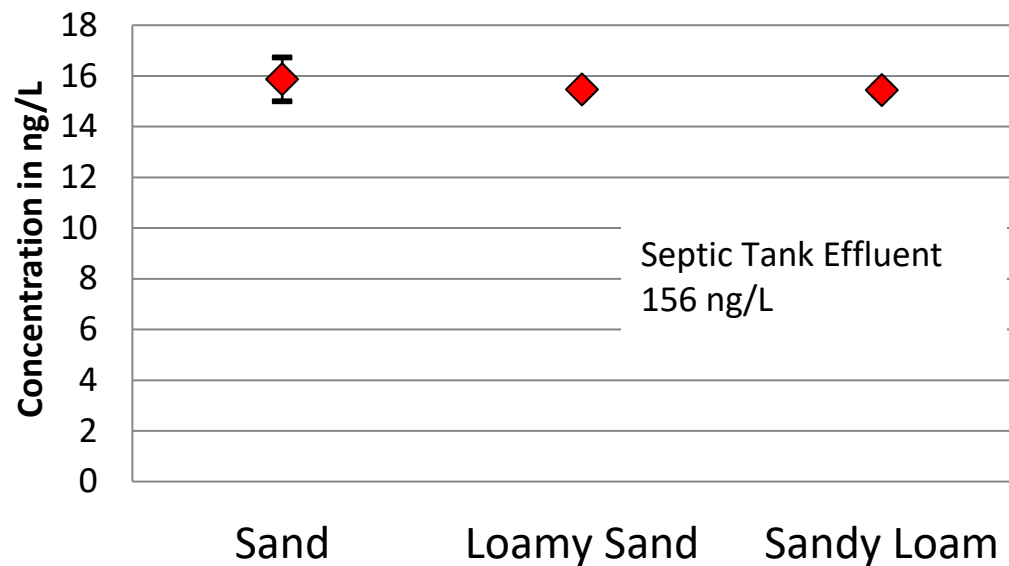


Furosemide, a 'water pill,' is used to reduce the swelling and fluid retention caused by various medical problems, including heart or liver disease.

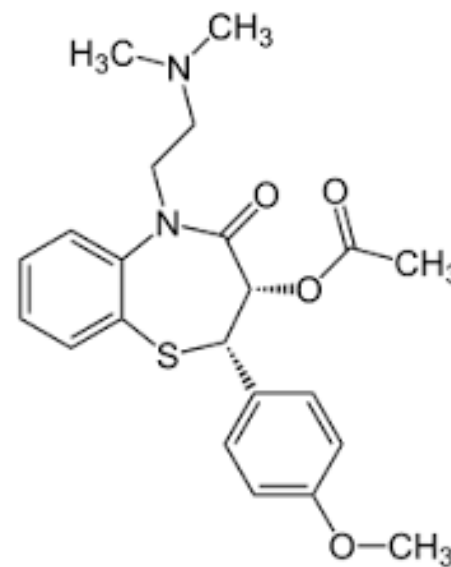
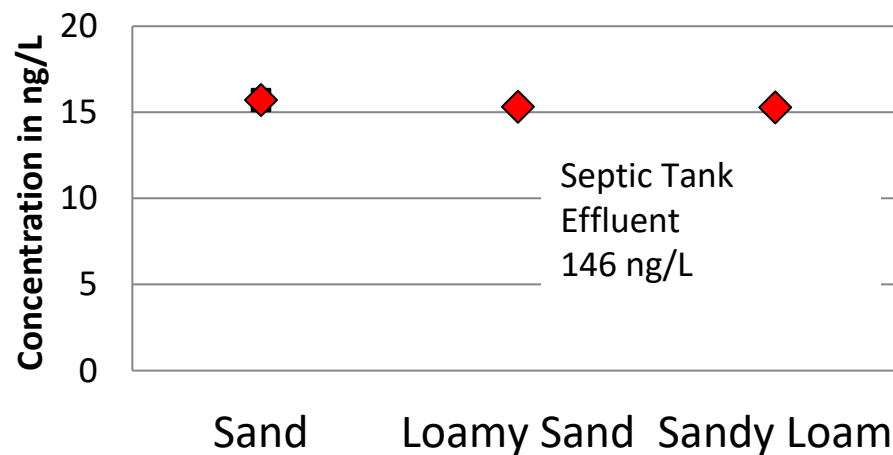


~ 80% removal

Diltiazem (May 2014)



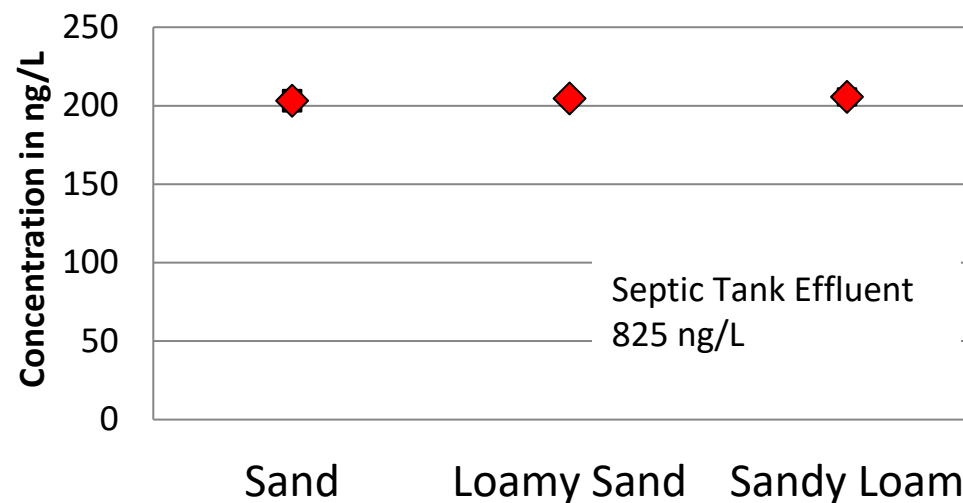
Diltiazem (June, 2014)



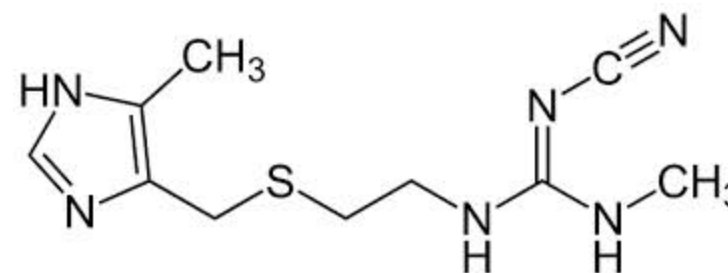
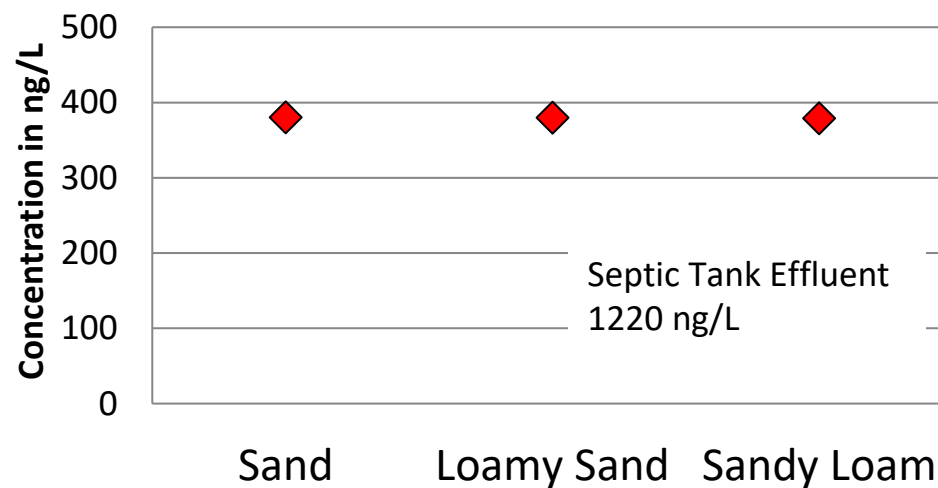


~ 65-75% removal

Cimetidine (May 2014)



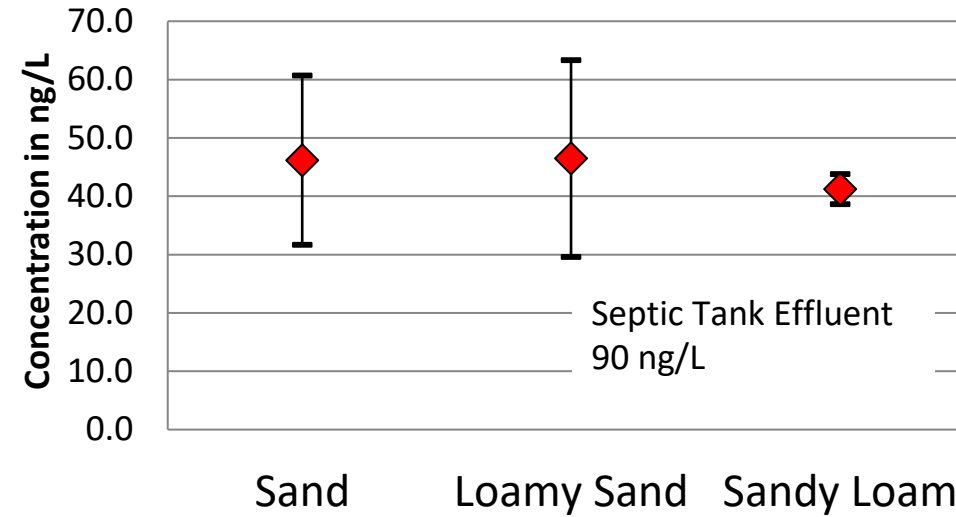
Cimetidine (June, 2014)



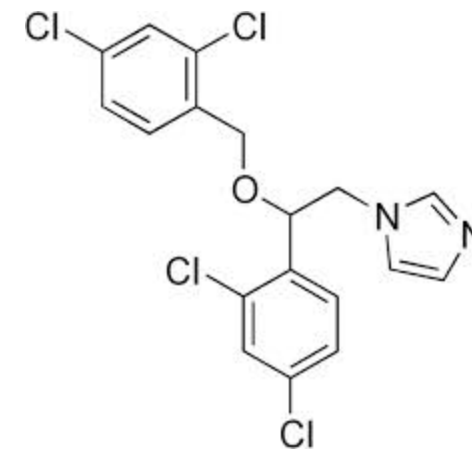
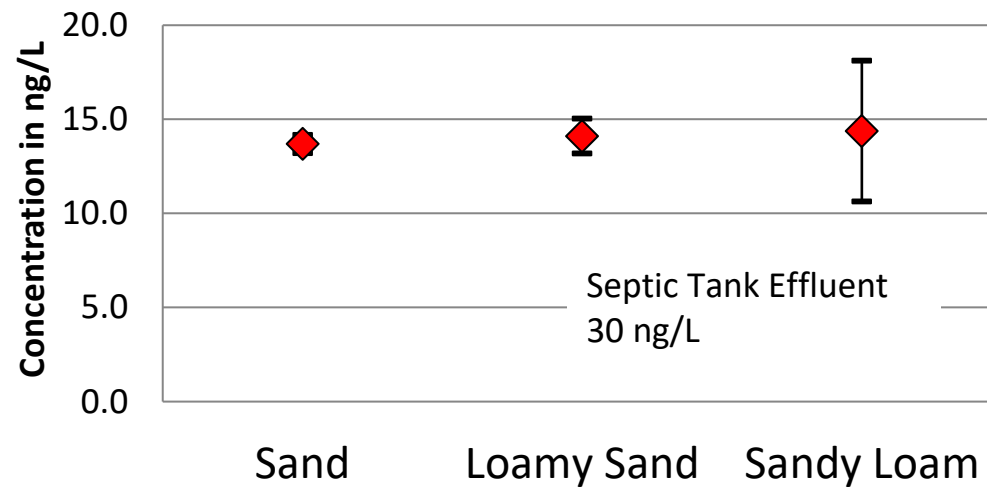


~ 50% Removal

Miconazole (May 2014)

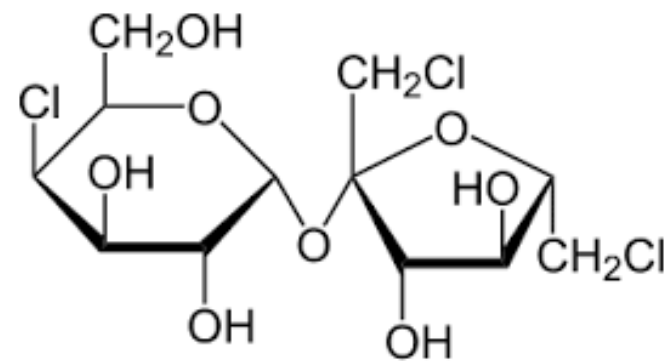
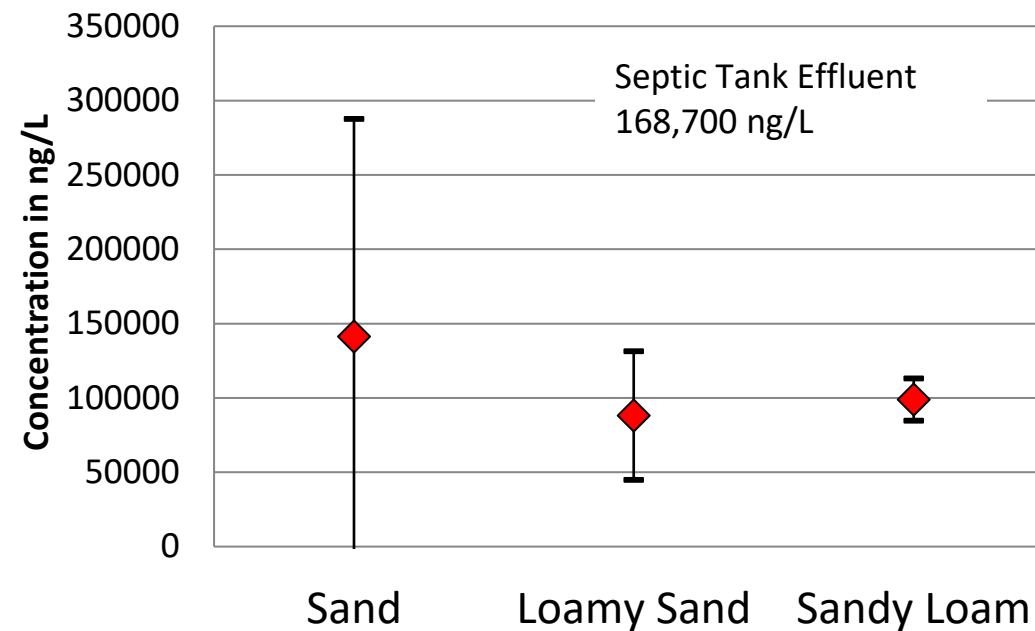


Miconazole (June, 2014)





Sucralose (June, 2014)



The general pattern of higher attenuation in soils containing 5%-10% fine material was found for acetaminophen, atenolol, atorvastatin, caffeine, DEET, diclofenac, ibuprofen, naproxen, sulfamethoxazole, and trimethoprim.





**No effect of soil
type**

No
significant
difference
with soil
type was
observed
with the
compounds

- Furosemide
- Propranolol
- Miconazole
- Cimetidine
- Diltiazem

Take Home Messages



Finer textured soils remove a higher percentage of many, but not all CECD tested.

Removal for some CEC improves over time (particularly in fine textured soils).

In general, onsite septic system drainfields in finer textured soils have better removal than many large centralized treatment technologies

Since 2002 WELL over 10,000 peer-reviewed articles and studies have focused on

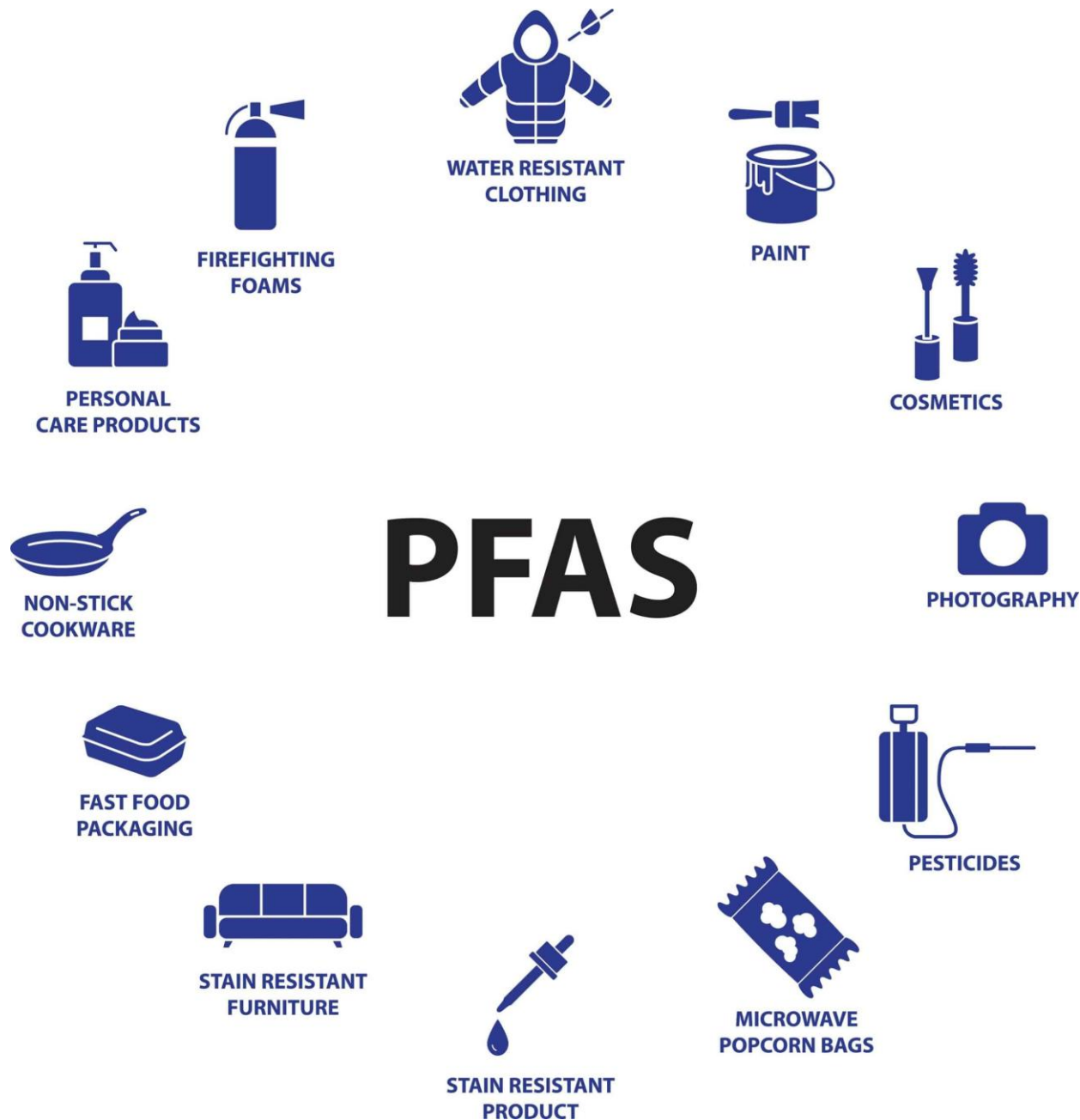
PFAS

IN A CLASS BY ITSELF

- Long-chain perfluoro carboxylic acids (PFCAs) which include PFOA
- Long chain Perfluoro sulfonic acids (PFSA), which include PFOS
- Along with their major precursors.

Poly- and Per- fluoroalkyl Substances

- └ Long chains of carbon with all fluorine attached
- └ Long chains of carbon with more than one fluorine attached (some hydrogens)



Most studies have focused on:

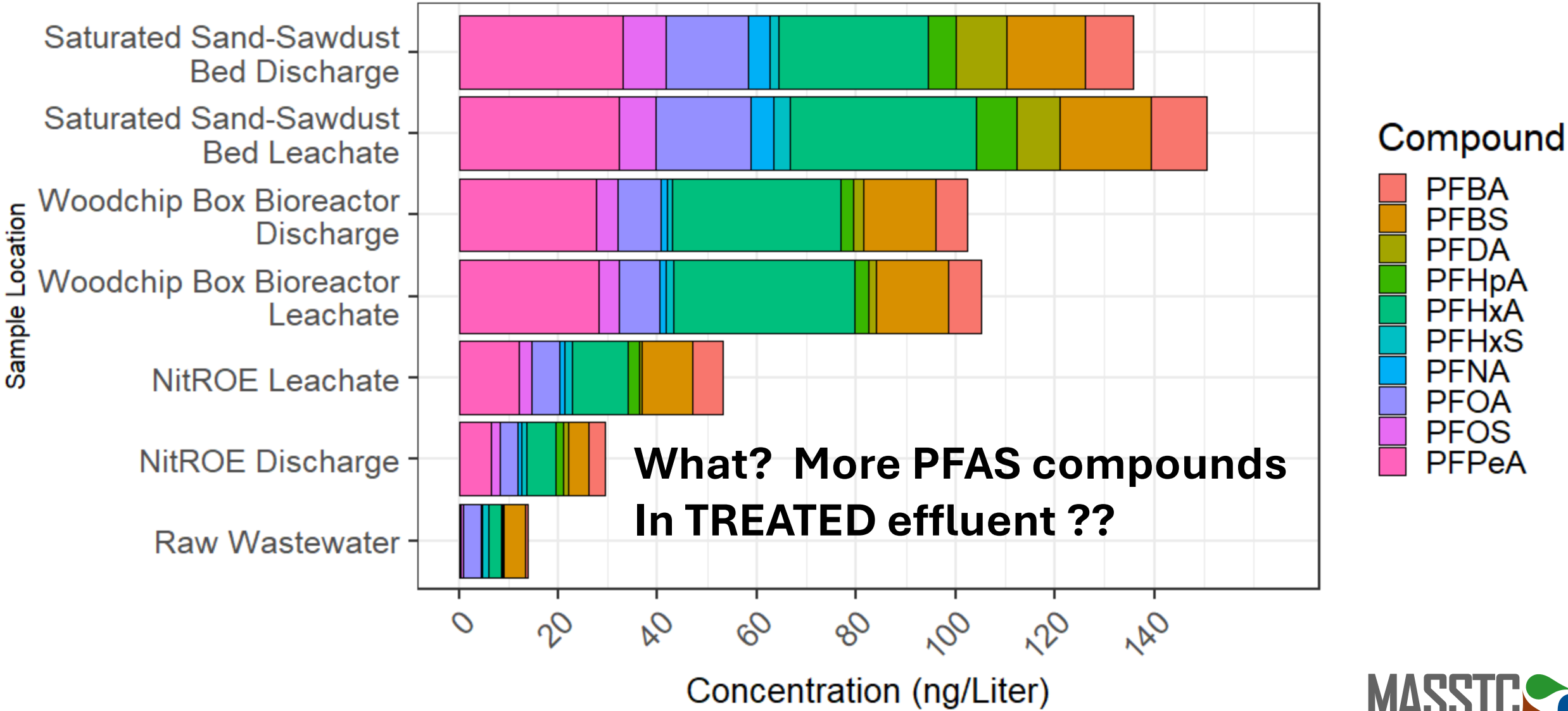
- Long-chain (8+C) perfluoro carboxylic acids which include PFOA
- Long-chain perfluoro sulfonic acids which include PFOS
- Precursors

The curse of the precursors

Confounding the analyses for PFAS

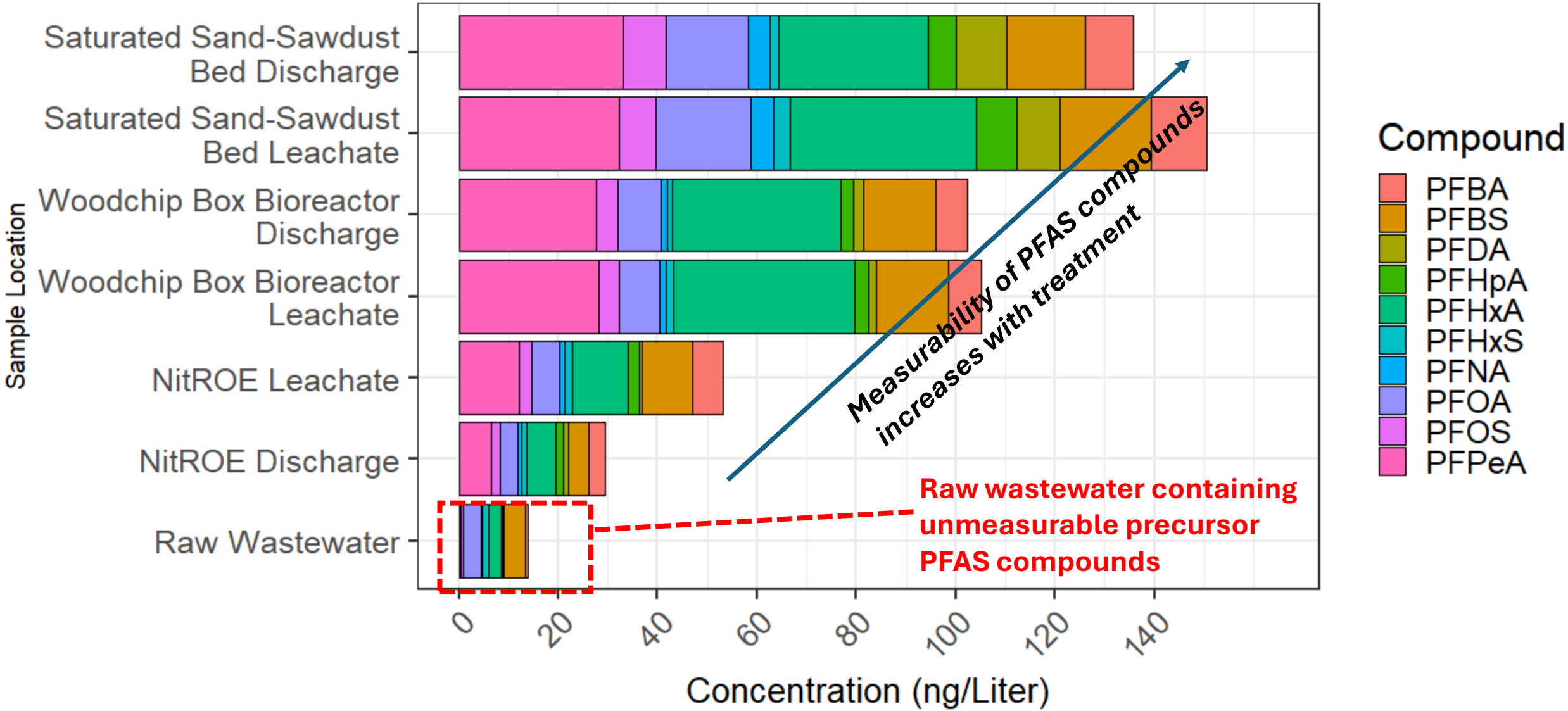
PFOS August 12, 2024

Samples collected at MASSTC



PFOS August 12, 2024

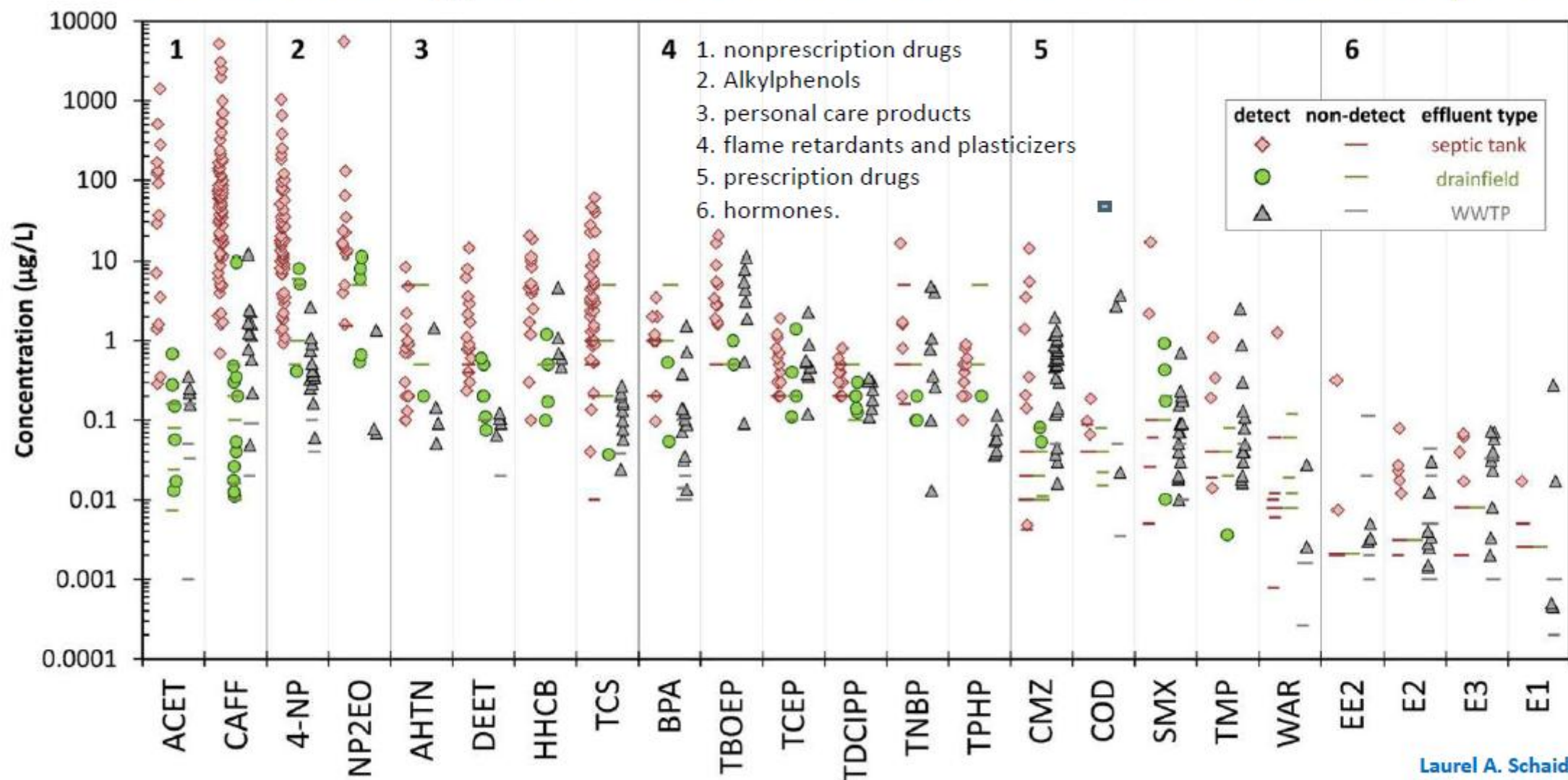
Samples collected at MASSTC



Now a word from our scientists

Numerous peer-reviewed studies have been conducted by research groups such as Silent Spring and various universities - too many to even summarize

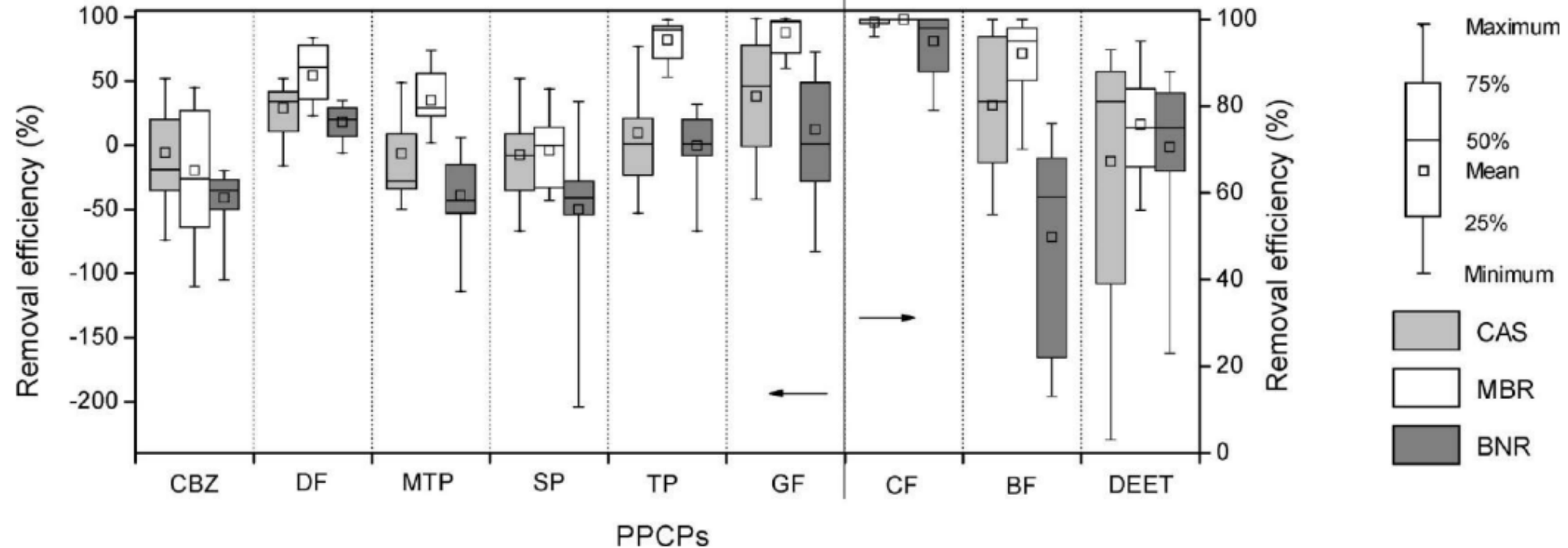
Effluent Organic Wastewater Contaminants (OWCs)



Laurel A. Schaider; Kathryn M. Rodgers;
Ruthann A. Rudel; *Environ. Sci. Technol.*
2017, 51, 7304-7317.

Concentrations of OWCs in septic tank effluent, drainfield effluent, and WWTP effluent. Horizontal lines show censoring values for systems where the median value was below the censoring value.

Process Removal Efficiencies



Comparison of the overall removal efficiencies by:

- Conventional Activated Sludge (CAS)
- Biological Nutrient Removal (BNR), and
- Membrane Bioreactor (MBR) processes.

- We have a very long way to go in our understanding of the PHAS chemistry
- There may be some de-fluorination through anaerobic pathways present in onsite septic systems but there is likely very little removal in septic systems or traditional wastewater treatment systems
- We have dug a very deep hole and left the ladder in the garage

Bottom Line

The background is a dark blue field with a network of thin, light blue lines connecting various nodes. Some nodes are simple circles, while others are more complex, resembling a candlestick chart. Numbers like '91.0', '89.635', and '130.9' are scattered throughout the network. The overall aesthetic is technical and data-driven.

What of all of this relates to septic systems?

A number of trends
emerge relevant to
treatment in septic
systems



=



Oxygen
is the key





Assessment of the environmental fate of endocrine disrupting chemicals in rivers

Elena Koumaki  , Daniel Mamais, Constantinos Noutsopoulos

 [Show more](#)

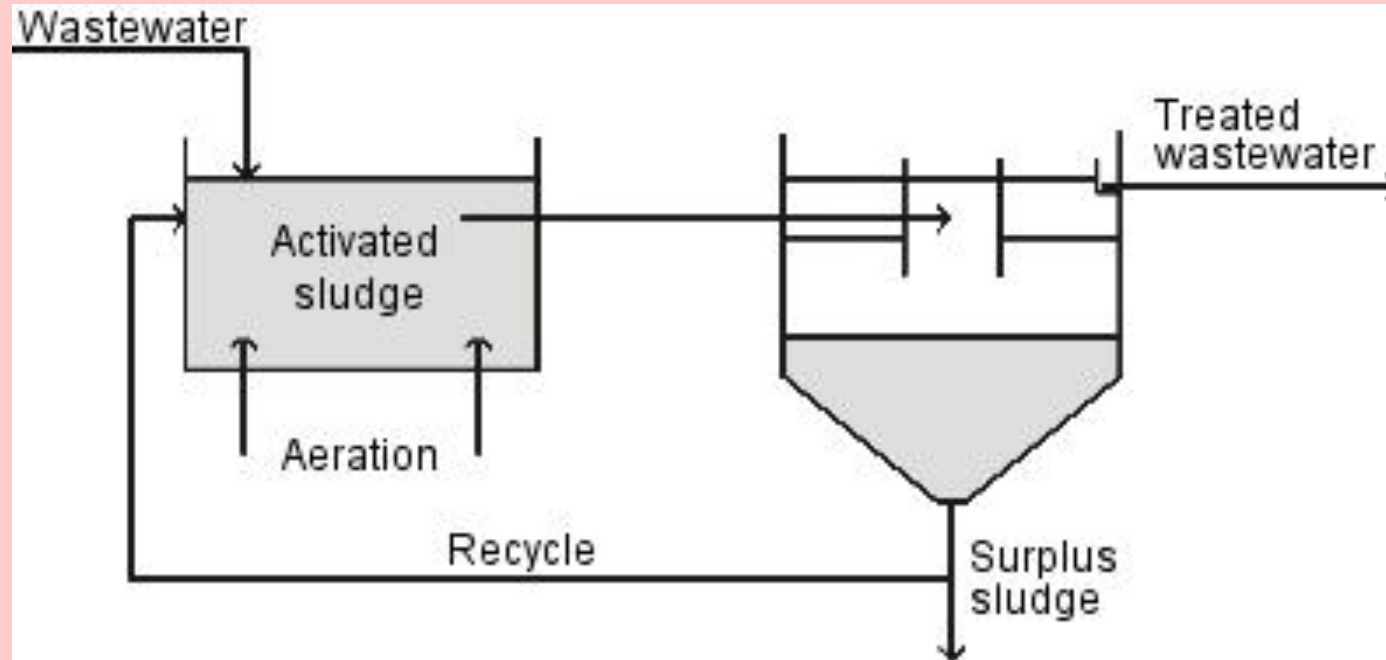
<https://doi.org/10.1016/j.scitotenv.2018.02.110>

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Well oxygenated conditions are most favorable for the reduction of endocrine disrupting compounds.



a lesson learned from conventional treatment plant studies



Data suggest that nitrifying organisms may use certain CEC as a carbon source.

Factors affecting the attenuation or removal of CEC in wastewater treatment

- Nature of the compound
- Oxygen availability
- Bacteria and other fauna diversity in the receiving environment
- Retention time during treatment

Take home messages

- Many pharmaceutical and personal care products, contain compounds that can disrupt the normal functioning of hormones in humans and wildlife.
- Although a major route for CEC entrance into the environment is wastewater disposal, the onsite septic system presents opportunity for significant treatment.
- Shallow-placed soil absorption systems remove > 90% of many CECs found in household wastewater.
- A more complete understanding of the principles of CEC removal in soils may offer opportunities to design optimization.
- A complete understanding of the range of mechanisms responsible for CEC removal in soils is not yet available.

Is there



HOPE ?

Complete transformation into an innocuous substance
(Carbon dioxide and water would be nice)

Is there any hope for eliminating PFAS
and other and similar compounds?

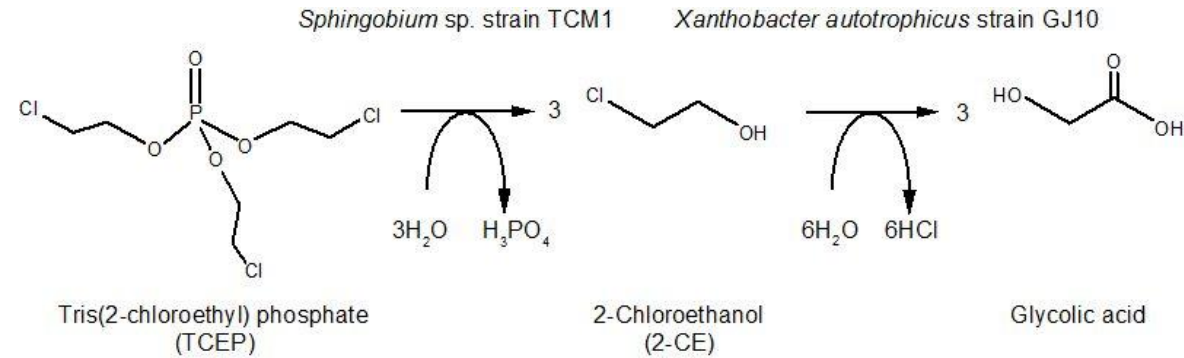
YES

CHANCE FAVORS THE PREPARED MIND

LOUIS PASTEUR

CHANCE FAVORS THE PREPARED BACTERIA (OR FUNGI...OR ALGA)

SUSAN DRACUT MONÂS



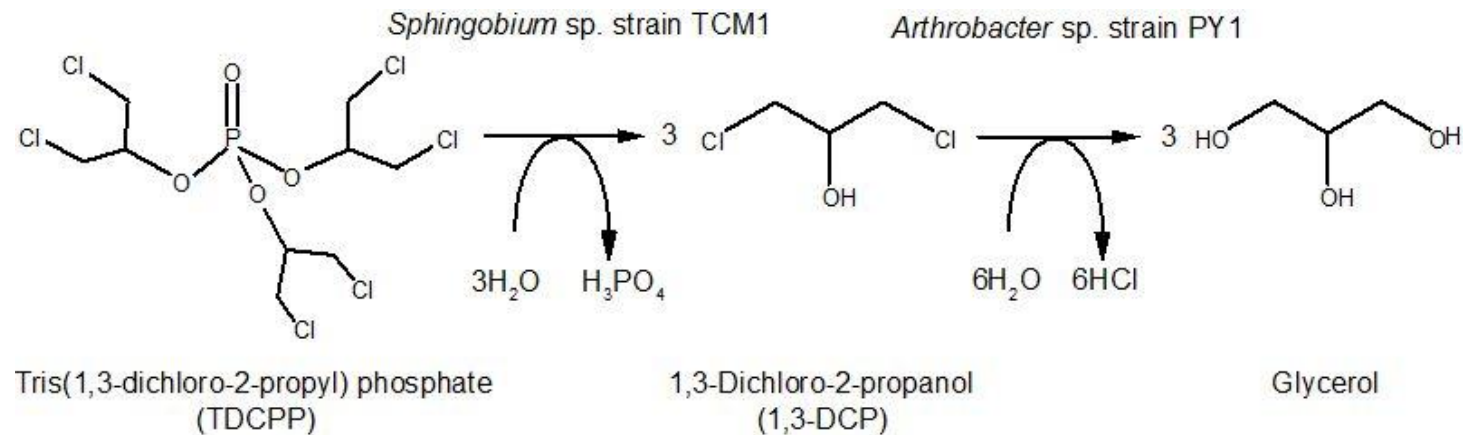
[Biochemistry, Genetics and Molecular Biology](#) » ["Environmental Biotechnology - New Approaches and Prospective Applications"](#), book edited by Marian Petre, ISBN 978-953-51-0972-3, Published: February 7, 2013 under [CC BY 3.0 license](#)

Chapter 5

Microbial Degradation of Persistent Organophosphorus Flame Retardants

By Shouji Takahashi, Katsumasa Abe and Yoshio Kera

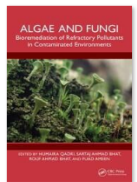
DOI: 10.5772/53749



New discoveries regarding bioremediation are made almost daily

Bacteria, fungi, algae and others have metabolic pathways and enzymatic systems that we are still discovering.....

The Truth is Out There (or maybe in there)



Chapter

Green algae bioremediation

By Anisa Ratnasari

Book [Algae and Fungi](#)

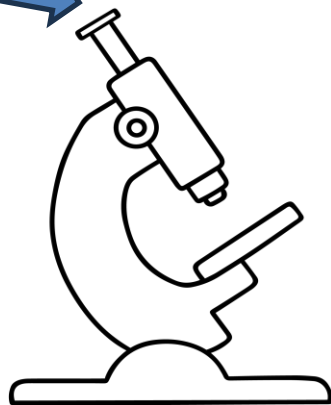
Edition 1st Edition

First Published 2025

Imprint CRC Press

Pages 20

eBook ISBN 9781003591337

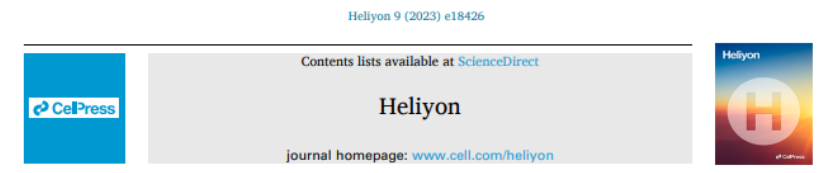


Microbial Biotechnology

REVIEW OPEN ACCESS

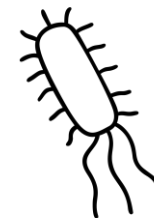
Microbes as Resources to Remove PPCPs and Improve Water Quality

Francesca Demaria¹ | Marcel Suleiman¹ | Philippe Corvini¹ | Pilar Junier²



Microbial degradation and transformation of PPCPs in aquatic environment: A review

Mathiyazhagan Narayanan^{a,*}, Sabariswaran Kandasamy^b, Jintae Lee^c, Selvaraj Barathi^{c,*}



WILEY

MICROBIAL BIOTECHNOLOGY

FINALLY !

OR

This could have been a really short lecture

**What about the impact of PPCPS and CECs
of septic system performance and function ?**

In General

**Pharmaceuticals and Personal Care Products (PPCPs) do
not impact the performance of a septic system or advanced
onsite treatment systems.**

**The possible exceptions to this are radiotherapy (the
impacts of which on the septic system are not known).**

Only a problem at high Concentrations?

- Process performance

- Decreasing rate of O₂ utilization
 - Ampicillin (20 mg/L)
- Decreasing rate of nitrification
 - Ciprofloxacin (0.2 mg/L), Ampicillin (20 mg/L), tetracycline (5 mg/L)
- Inhibition of denitrification
 - Chlorotetracycline
- Poorer removal of orthophosphate
 - Chlorotetracycline (10 mg/L), erythromycin (5 mg/L)

- Shifting microbial ecology

- Loss of accumulibacter, increase in competibacter
 - erythromycin (5 mg/L)

- Sludge behavior

- Reduction in attached biomass and floc size
 - Ciprofloxacin (0.2 mg/L),
- Sludge bulking
 - tetracycline (5 mg/L)

- Enzymatic impacts

- Dehydrogenase inhibition
 - Ampicillin
- Reductase
 - Chlorotetracycline

- Reactive Oxygen Species (ROS)

- Increased production

Source:

Dave Reckhow
Dept. of Civil & Environmental Engineering
UMass Amherst

Questions



George Heufelder M.S., R.S.
Environmental Specialist
gheufelder@capecod.gov

