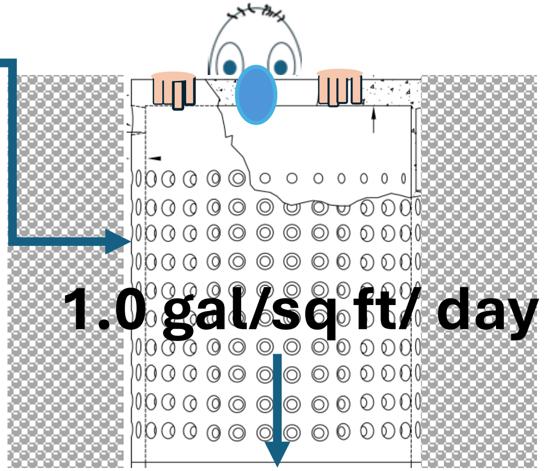
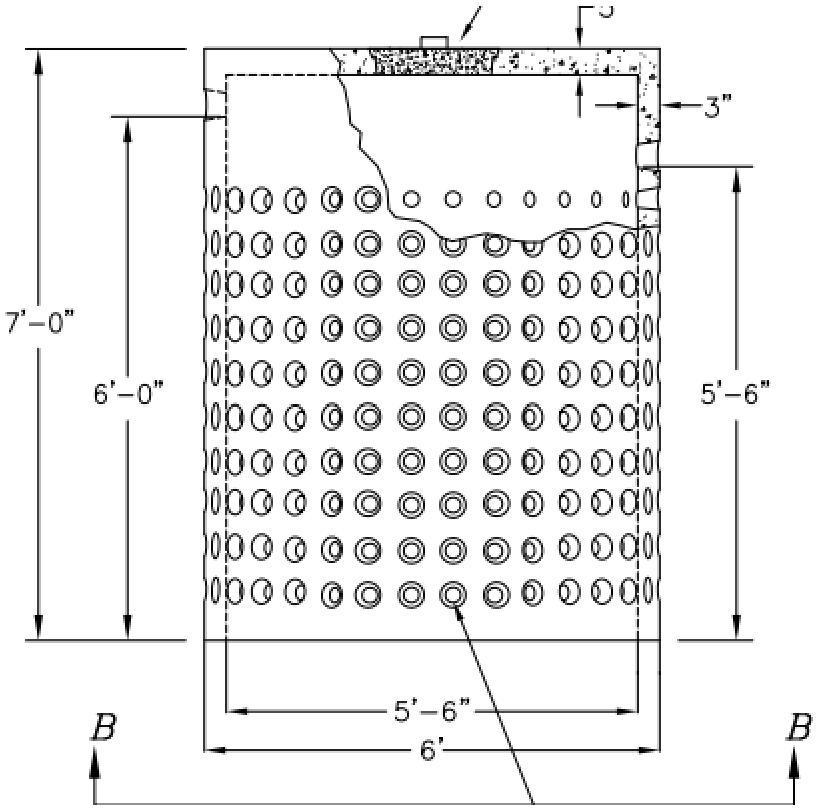
Remember when....





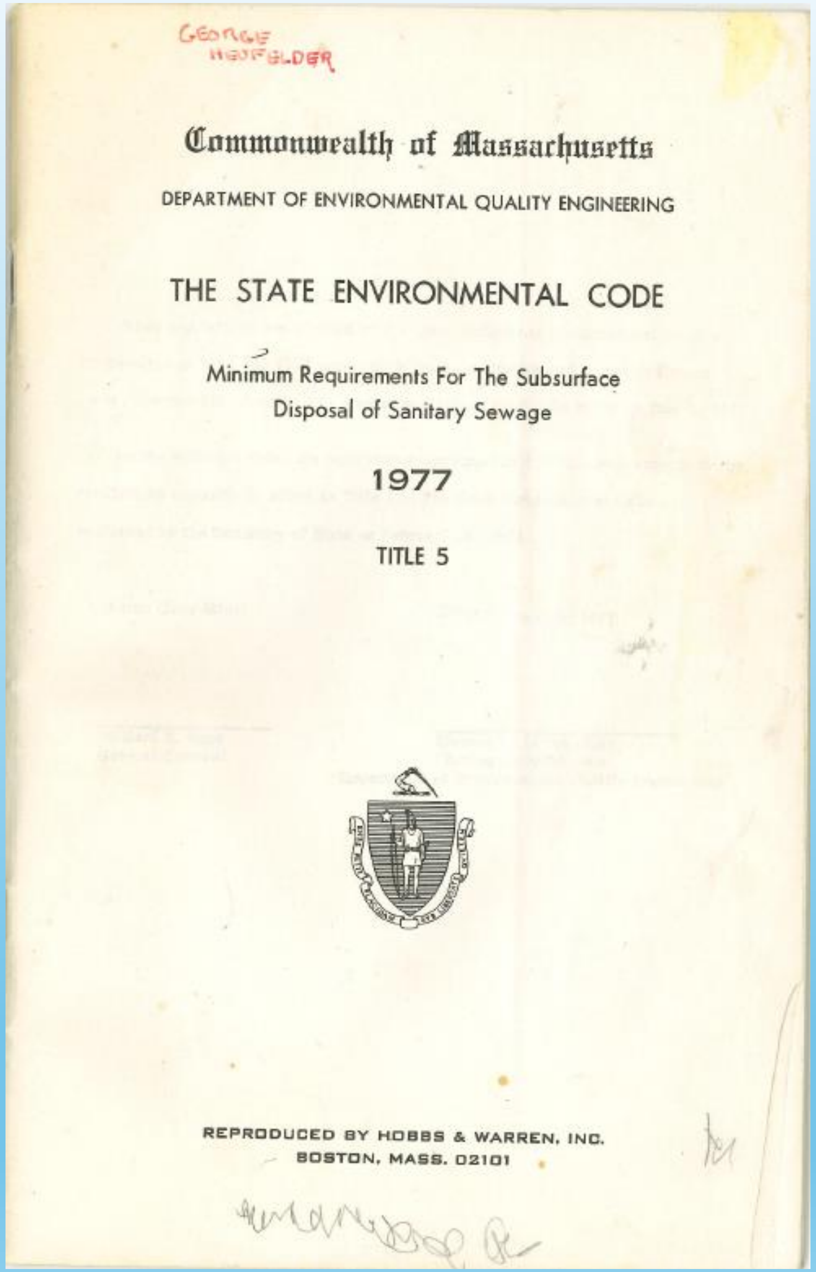
life was the pits?

A new look at an old technology for the polishing of pretreated septic tank effluent.

George Heufelder, M.S., R.S.
Environmental Specialist | Health and Environment
Massachusetts Alternative Septic System Test Center

This project was funded 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 report 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 trip back
in time…
Source:https://www.nasa.gov/image-galleries/



GEORGE HEUFELDER

Commonwealth of Massachusetts

DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING

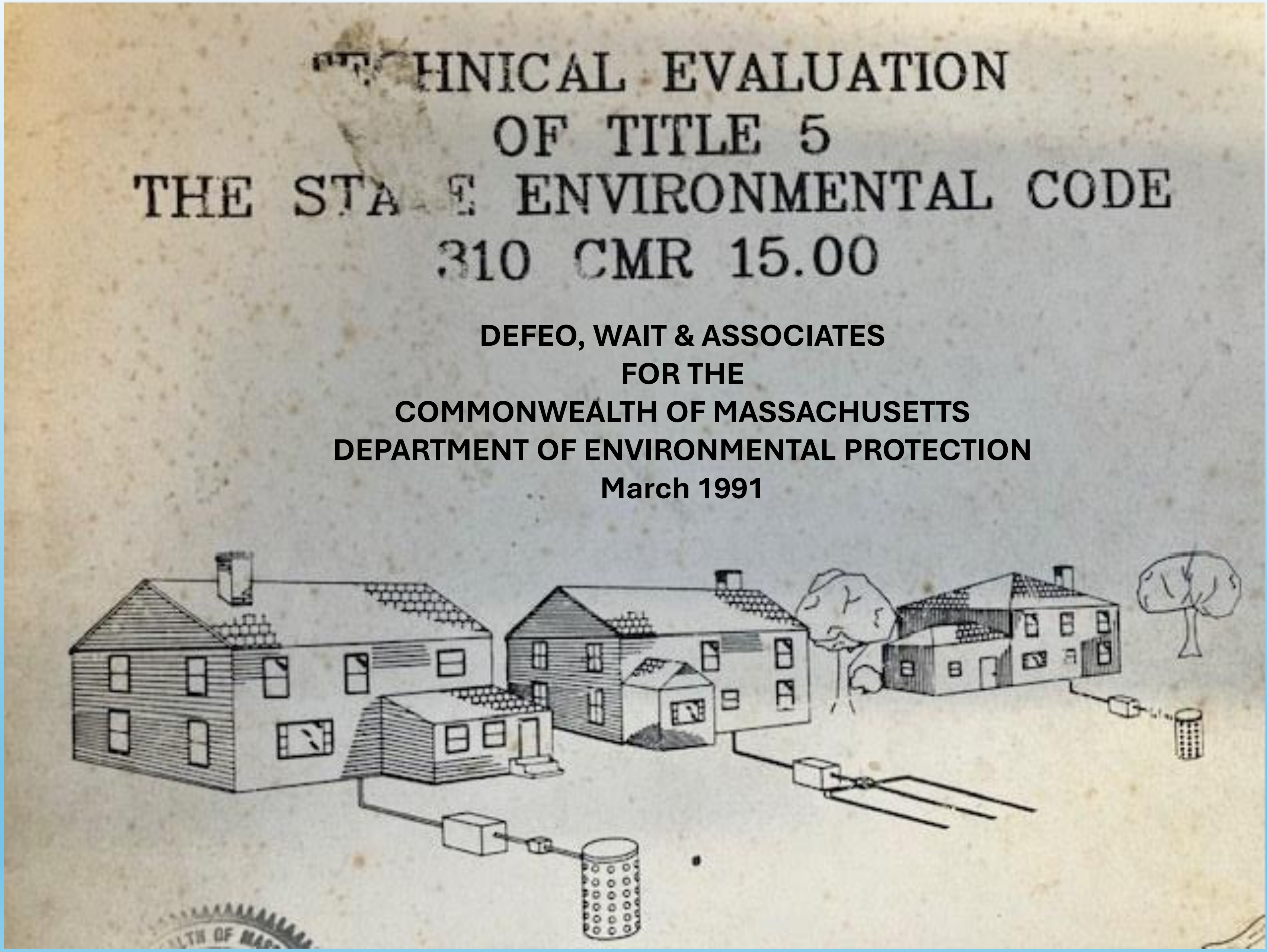
THE STATE ENVIRONMENTAL CODE

Minimum Requirements For The Subsurface
Disposal of Sanitary Sewage

1977

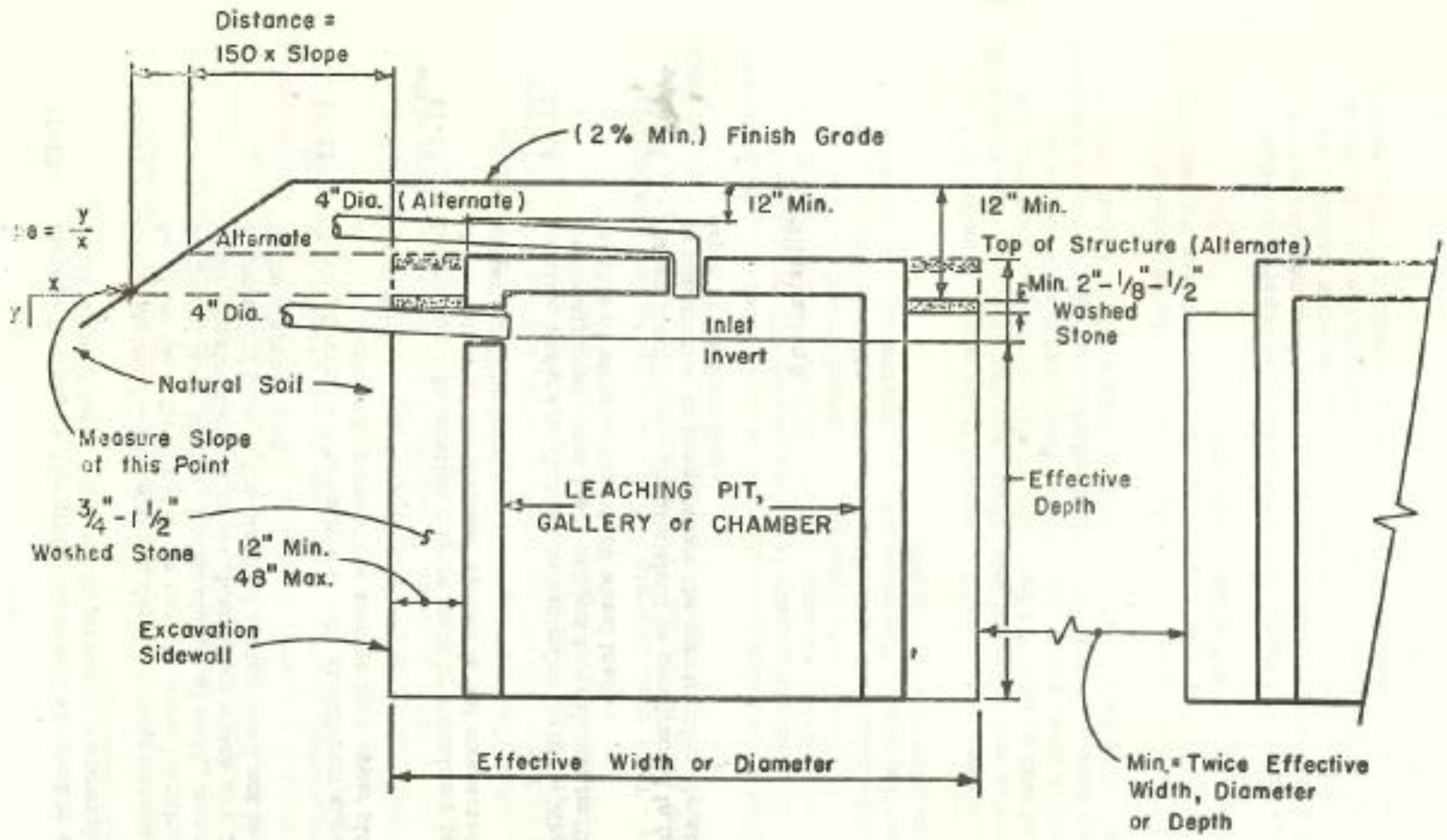
TITLE 5

REPRODUCED BY HOBBS & WARREN, INC.
BOSTON, MASS. 02101



TECHNICAL EVALUATION
OF TITLE 5
THE STATE ENVIRONMENTAL CODE
310 CMR 15.00

DEFEO, WAIT & ASSOCIATES
FOR THE
COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
March 1991



LEACHING PITS, GALLERIES, CHAMBERS

No Scale

Illustration A

Source:
THE STATE ENVIRONMENTAL CODE
Minimum Requirements For The Subsurface Disposal of Sanitary Wastes
1977
TITLE 5

REGULATION 11. LEACHING PITS

Source:
THE STATE ENVIRONMENTAL CODE
Minimum Requirements For The Subsurface Disposal of Sanitary Wastes
1977
TITLE 5

11.1 Use - Leaching pits are preferred where their installation is possible.

REGULATION 11. LEACHING PITS *

11.1 Use – Leaching pits are preferred where their installation is possible.

REGULATION 11. LEACHING PITS

11.1 Use - Leaching pits are preferred where their installation is possible.

REGULATION 11. LEACHING PITS *

11.1 Use – Leaching pits are preferred where their installation is possible.

Source:
THE STATE ENVIRONMENTAL CODE
Minimum Requirements For The
Subsurface Disposal of Sanitary Wastes
1977
TITLE 5

THE STATE ENVIRONMENTAL CODE

Minimum Requirements For The Subsurface Disposal of Sanitary Wastes

1977 - TITLE 5

From Disposal

To Treatment

THE STATE ENVIRONMENTAL CODE

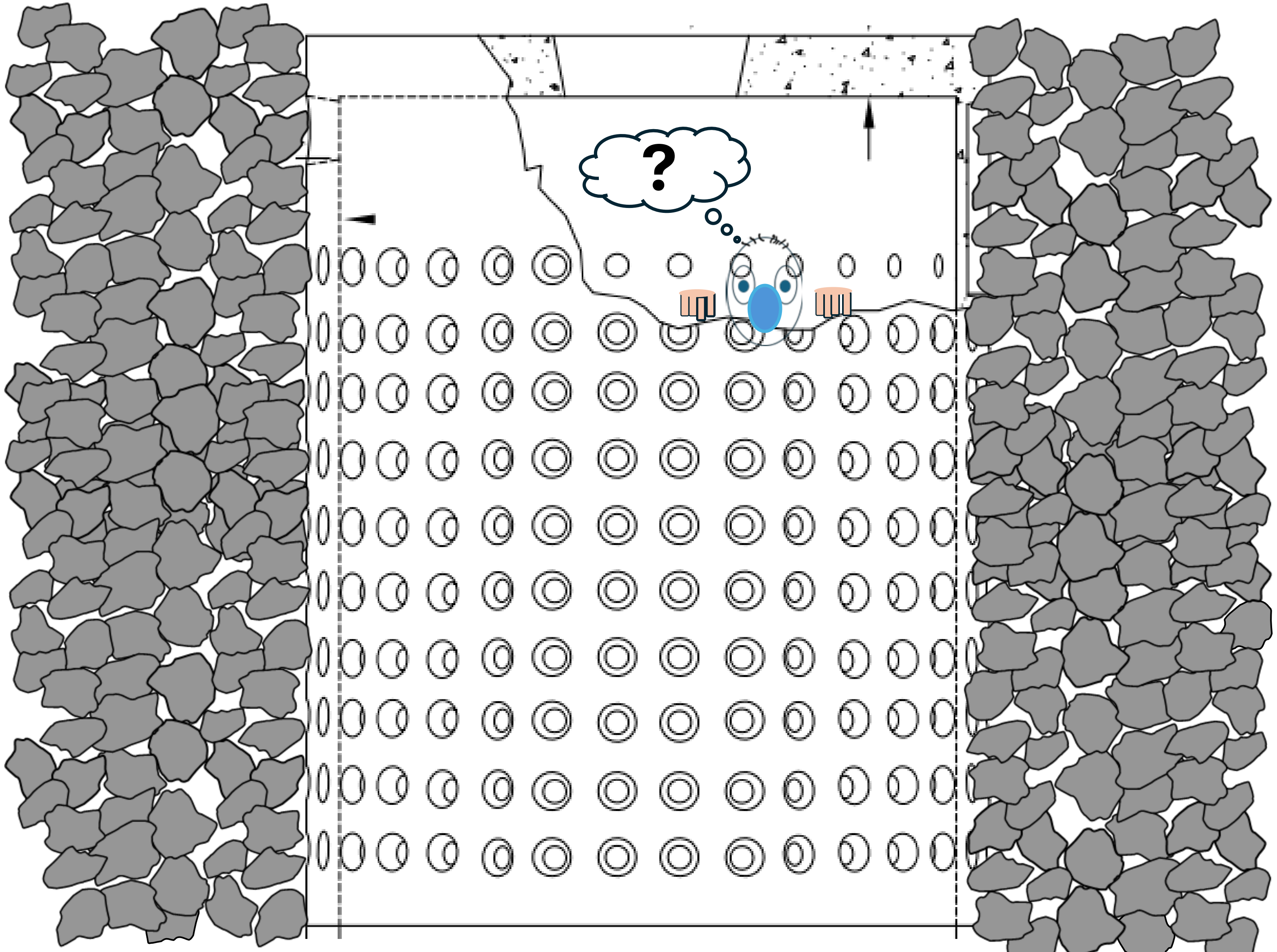
TITLE 5: STANDARD REQUIREMENTS FOR THE SITING, CONSTRUCTION, INSPECTION, UPGRADE AND EXPANSION OF ON-SITE SEWAGE TREATMENT AND DISPOSAL SYSTEMS AND FOR THE TRANSPORT AND DISPOSAL OF SEPTAGE

(1995 →→→→→→→→→→ revisions →→→2024)

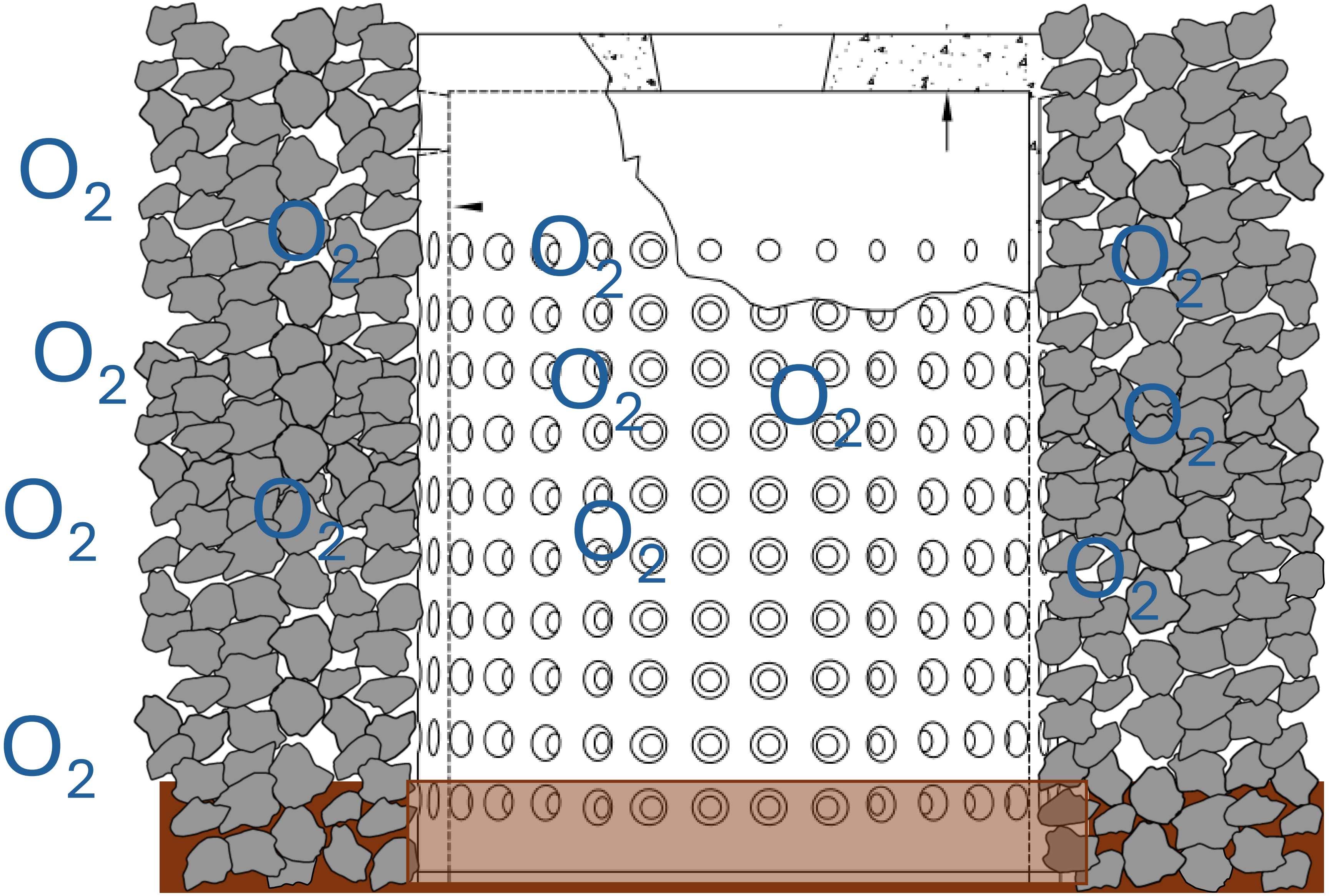
Basically, the “new” code (1995) transitioned onsite wastewater treatment regulations from regulating “disposal” and encouraging “treatment” .

So, what was wrong with deep leach pits?

And why were they taken out of the allowances in the new regulations ?

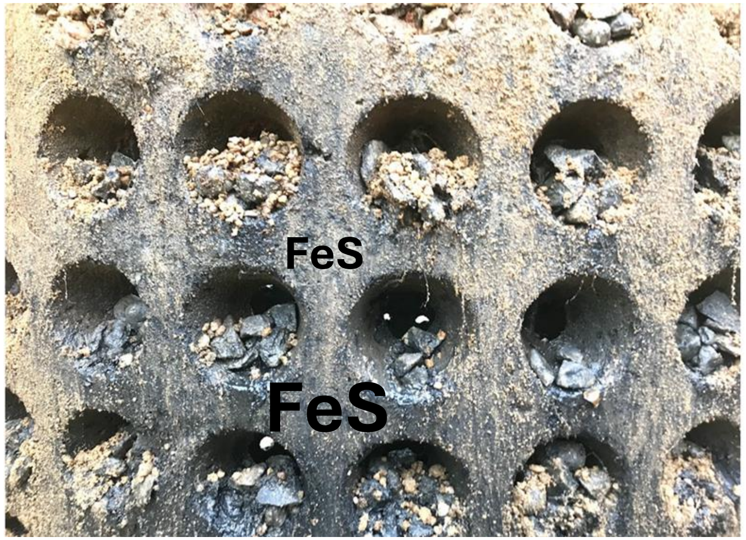


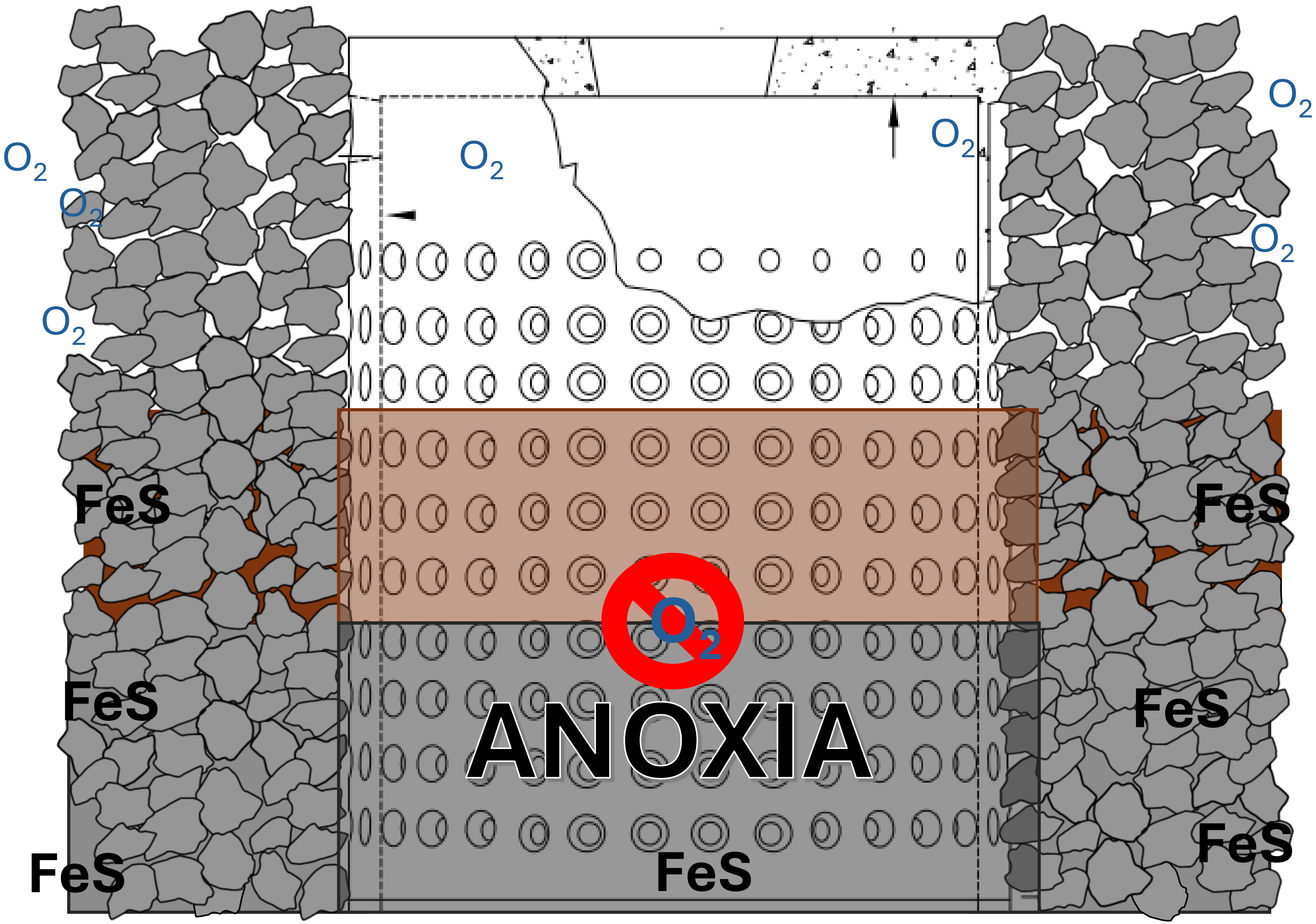
Nothing initially



But soon.....


FeS


FeS
FeS


O2
O2
O2
O2
O2
O2
O2
FeS
FeS
FeS
FeS
FeS
FeS
O2
ANOXIA
FeS

So basically…

- Hydraulic loads high and localized
- Promotes anoxia in the treatment area which clogs infiltrative surfaces through the production of EPS.

Causes of anoxia and failure of leach pits to treat wastewater

- Biochemical Oxygen Demand of septic tank effluent (BOD)
- BOD coupled with high hydraulic loading rates
- Liquid and saturation precludes oxygen transfer which would break down organics more readily

Where did the pits go and why?

"A maximum of 2 feet of sidewall depth should be credited toward calculation of the effective leaching area........

Recommendation -DeFeo, Wait & Associates, Inc. Technical Evaluation – Title 5

- Prevent excessive hydraulic loading
- Allow for better aeration and stabilization of wastes
- Allow for longer residence times (=treatment)

By the way….

Technically, deep leaching pits didn't *actually* get eliminated in the new code change. It is only the allowance for any more that two feet of sidewall "credit" for effective leaching area that got eliminated (and of course the loading rate).

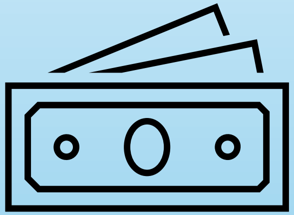

A new look
at an old technology


Why

So the question is..

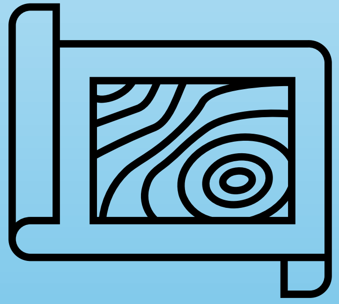
What if you could treat wastewater “enough” so that the treated wastewater could then just be disposed of ?

Cost and Space



1 - $3,000/$10000 = .7 = 70%

~ 70% cost savings



1 - 133/446 = .70 = 70%

~70% space savings

The experiment

- Take three lignocellulose (wood-based) denitrification technologies and discharge the effluent to a small footprint leaching structure (like a leaching pit) at previously allowed hydraulic loading rates

- Measure selected contaminants below the leach pits

- Determine whether this strategy offers the same degree of environmental protection as is afforded by a standard leachfield

Why wood-based systems?

The same laccases and peroxidase enzymes that facilitate the cellulose-based carbon sourcing for denitrification in wood-based systems, may be able to "disassemble" many organic contaminants of emerging concern.

Why wood-based systems?

Bacteria and viruses are of main concern and some of the wood-based systems have some efficacy at removing them before the reach the soil treatment areas

Finally….

Wood-based denitrification systems are at the top the recently-released **Best Available Nitrogen Removing Technology** list of the Massachusetts Department of Environmental Protection. Impediments to their acceptance includes costs and space requirements. This effort was to compile data to support a lower cost option that has a more compact overall footprint.

Footprint Comparisons

How much could we really save?

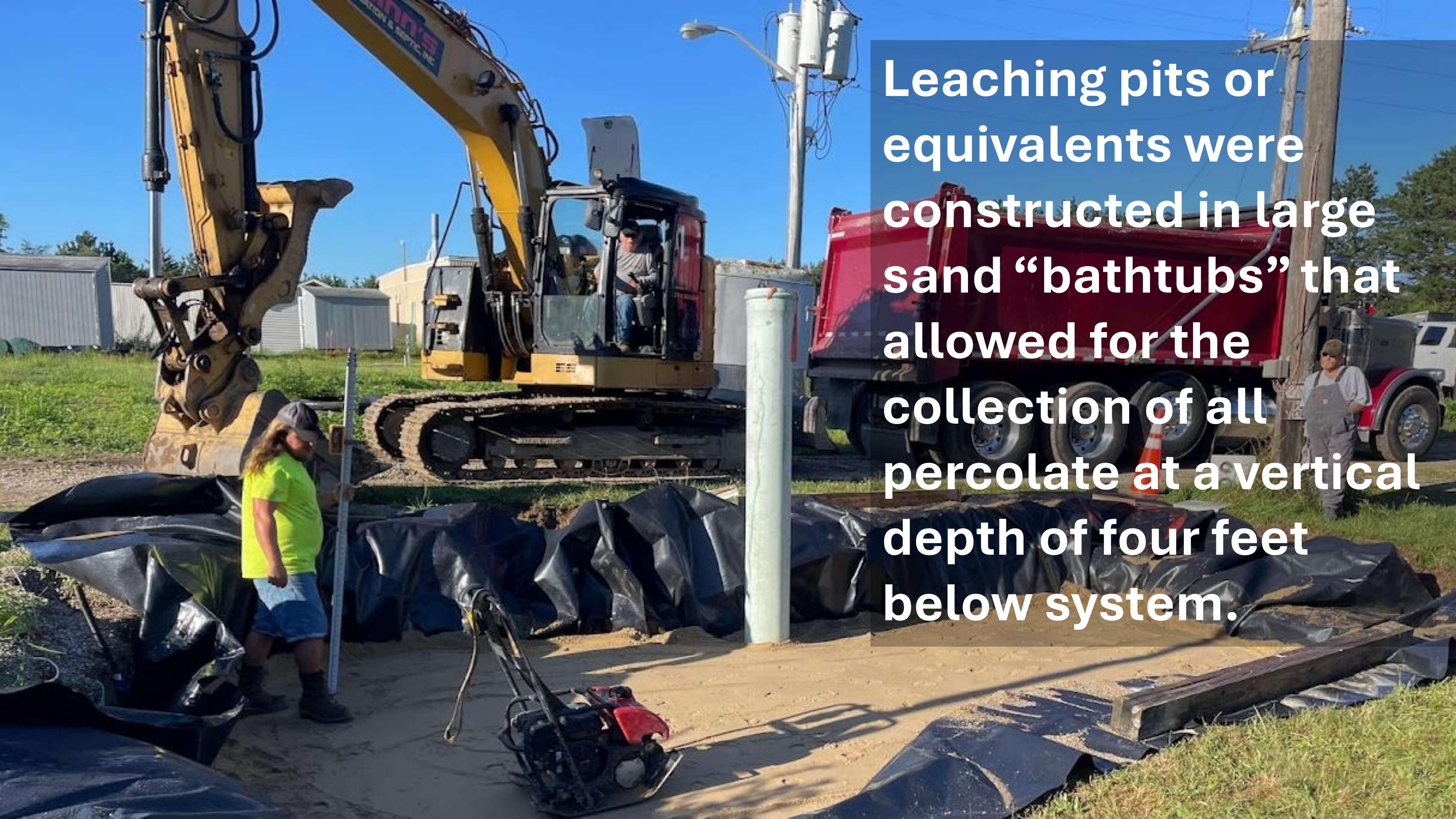
Three Bedroom Home

	Areal area required (Sq ft)	Percent of Standard Area Required
Standard Leachfield (bed design)	446	
Leach Pit (circular pit - 6 ft diameter - 3.5 ft aggregate)	133	30%
Leach Chamber (8.5 x 5.75 ft with 2 ft of aggregate)	122	27%

***** Remember that the two ft. maximum sidewall allowance is <u>preserved</u>***

A single leaching galley with 1 ‘ of aggregate used to simulate the use of a round leach pit …

due to the   difficulty in containing the aggregate during the test cell construction.



Leaching pits or equivalents were constructed in large sand "bathtubs" that allowed for the collection of all percolate at a vertical depth of four feet below system.


Containment liner
Leaching galley
Temporary support for aggregate stone
(pulled up and out as backfilled
Sampling port


Director
Leaching galley access
Sampling port
Containment liner boundary

3

Woodchip box bioreactor

Proprietary woodchip bioreactor NitROE™

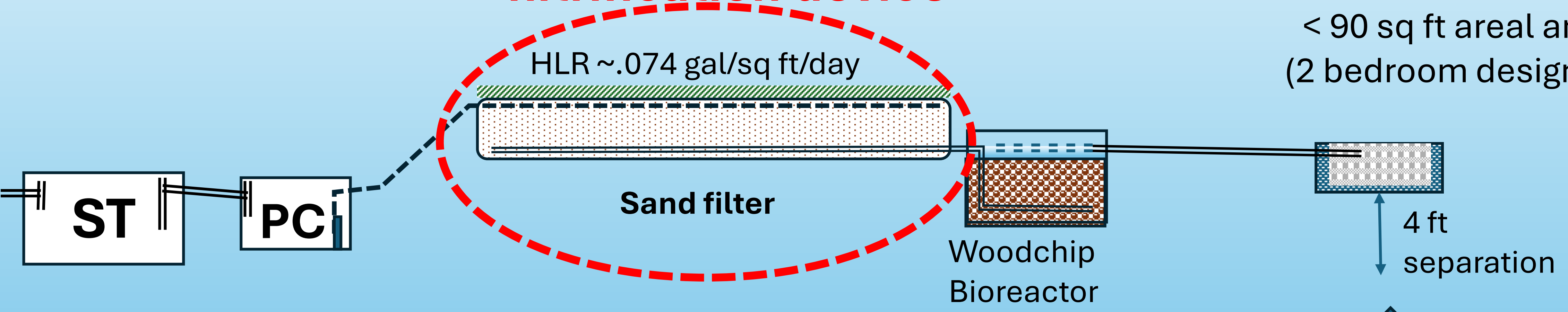
Lined sand-sawdust bioreactor beneath a standard leachfield

System 1

Woodchip box bioreactor (analogous but ≠ to a Nitrex™)

Could use any efficient nitrification device

Single leach chamber with
1’ stone
< 90 sq ft areal area
(2 bedroom design)



Hydraulic Loading rate
Bottom = 1 gal/sq ft/day
Sides = 2.5 gal/sq ft/day

System 2

HLR ~.074 gal/sq ft/day

Lined sand sawdust bioreactor beneath standard leachfield

Single leach chamber with stone aggregate
< 100 sq ft areal area
(2 bedroom design)

4 ft separation

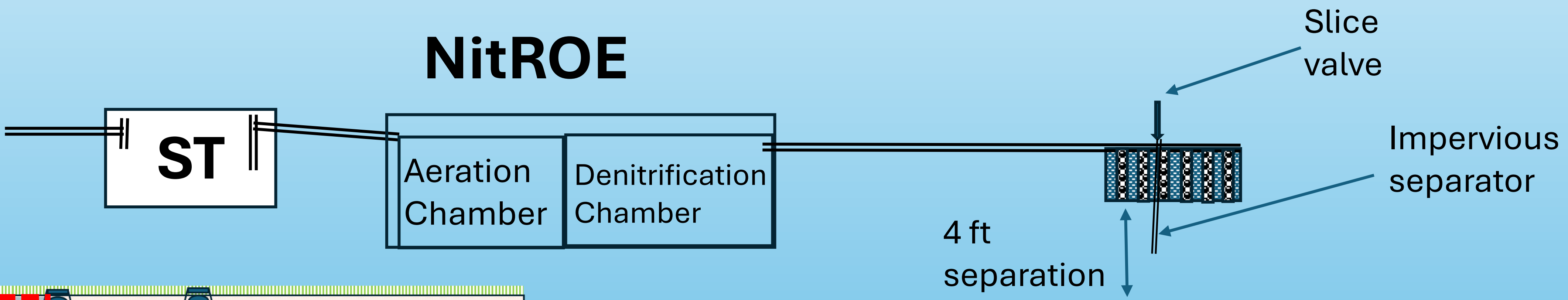
Over 7.7 years avg. Total Nitrogen 8.0 mg/L

Hydraulic Loading rate
Bottom = 1 gal/sq ft/day
Sides = 2.5 gal/sq ft/day

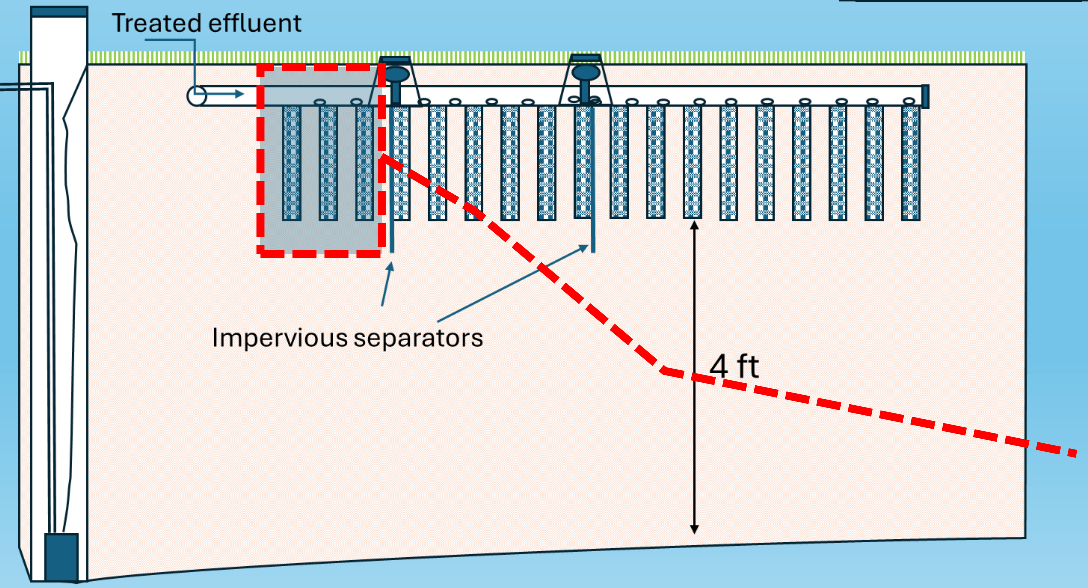
System 3

Single section GST™

< 40 sq ft areal area



Hydraulic Loading rate
Bottom = 1 gal/sq ft/day
Sides = > 2.5 gal/sq ft/day



Only used small portion of system for testing period

“Leach Pit”

- Aggregate
- Side loading 2.5 gal/sq ft/day
- Bottom Loading 1 gal/sq ft/day
- Two-foot sidewall maximum
- Four ft. to vertical separation to collection point
- “Title 5” sand
- Gravity fed
- Loved and cared for
- Maximum design load for 365 days/year
- Not street legal

Stone in Pipe Trench

- Aggregate
- Side loading 0.74 gal/sq ft/day
- Bottom Loading 0.74 gal/sq ft/day
- Two-foot sidewall maximum
- Four ft. vertical separation to collection point
- “Title 5” sand
- Gravity fed
- Loved and cared for
- Maximum design load for 365 days/year
- Street legal

Results

Bacteria

Viruses

Selected CECs

PFAS Compounds

Fecal Coliform
A generally-accepted standard of public health risk

- **Includes inhabitants of the human gut and hence in feces (acts as a surrogate measure of pathogens)**
- **Includes *Escherichia coli***
- **Used because they are easily cultured (not like the 220+ human viruses that they are supposed to surrogate)**

Assessing the risk

What metric to use in assessing the risk for exposure to bacterial and viral pathogens

The goal is to reduce the <u>percentage</u> of pathogens as the water passes through the various stages of treatment to an agreed-upon "acceptable" level before exposure to humans.

LOG **R**EDUCTION **V**ALUE

90%
99%
99.9%
99.99%
99.999%
99.9999%

A brief lesson in log reduction

The goal is to reduce the percentage of pathogens as the water passes through the various stages of treatment to an agreed-upon "acceptable" level before exposure to humans.

LRV (LOG REDUCTION VALUE)

A lesson in logs (base 10)

1 log = 90% reduction
2 logs = 99% reduction
3 logs = 99.9% reduction
4 logs = 99.99% reduction
5 logs = 99.999 % reduction
6 logs = 99.9999 % reduction

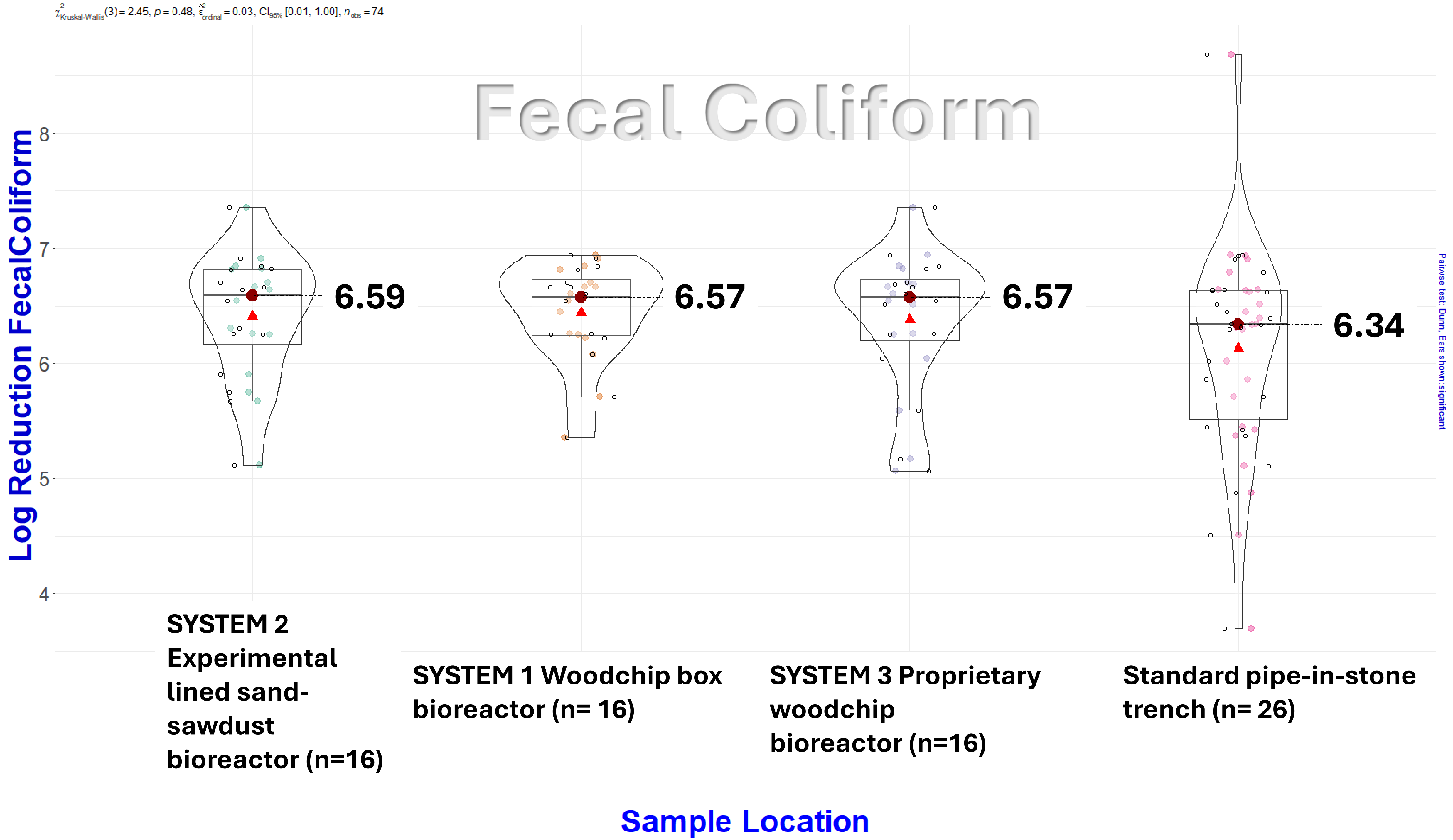
A lesson in logs (base 10)

1 log = 90% reduction
2 log = 99% reduction
3 log = 99.9% reduction
4 log = 99.99% reduction
5 log = 99.999 % reduction
6 log = 99.9999 % reduction
7 log = 99.99999% reduction
8 log = 99.999999% reduction
12 log=99.9999999999% reduction

The approximate level of removal afforded by standard systems at 4-5 ft of passage through sand.

WHO for unrestricted irrigation

California for direct reuse



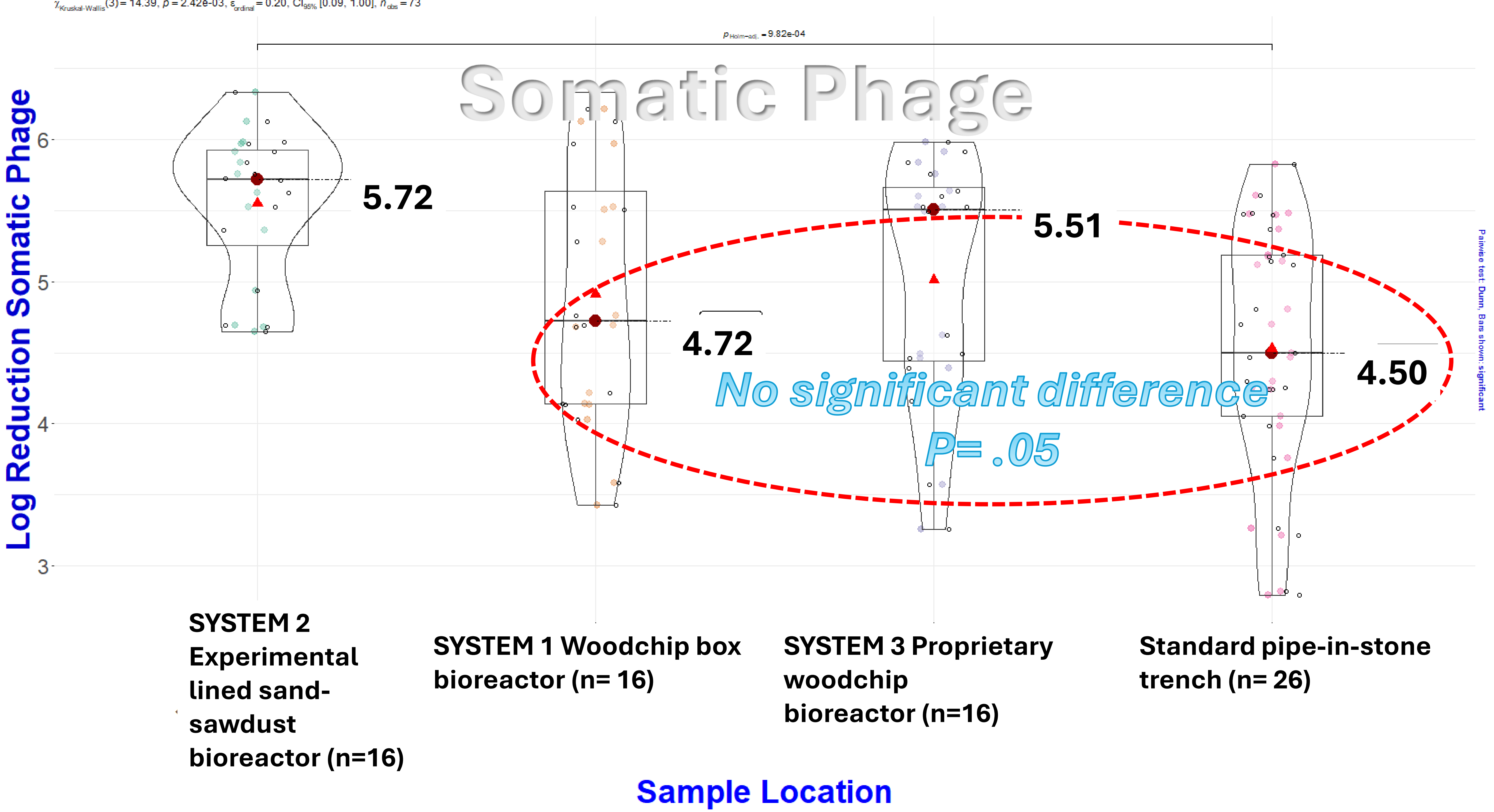
$\chi^2_{Kruskal-Wallis}(3) = 2.45$, $p = 0.48$, $\hat{\epsilon}^2_{ordinal} = 0.03$, $CI_{95\%}$ [0.01, 1.00], $n_{obs} = 74$
Fecal Coliform
Log Reduction FecalColiform
8
7
6
5
4
6.59
6.57
6.57
6.34
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=16)
SYSTEM 1 Woodchip box bioreactor (n= 16)
SYSTEM 3 Proprietary woodchip bioreactor (n=16)
Standard pipe-in-stone trench (n= 26)
Sample Location
Pairwise test: Dunn, Bars shown: significant

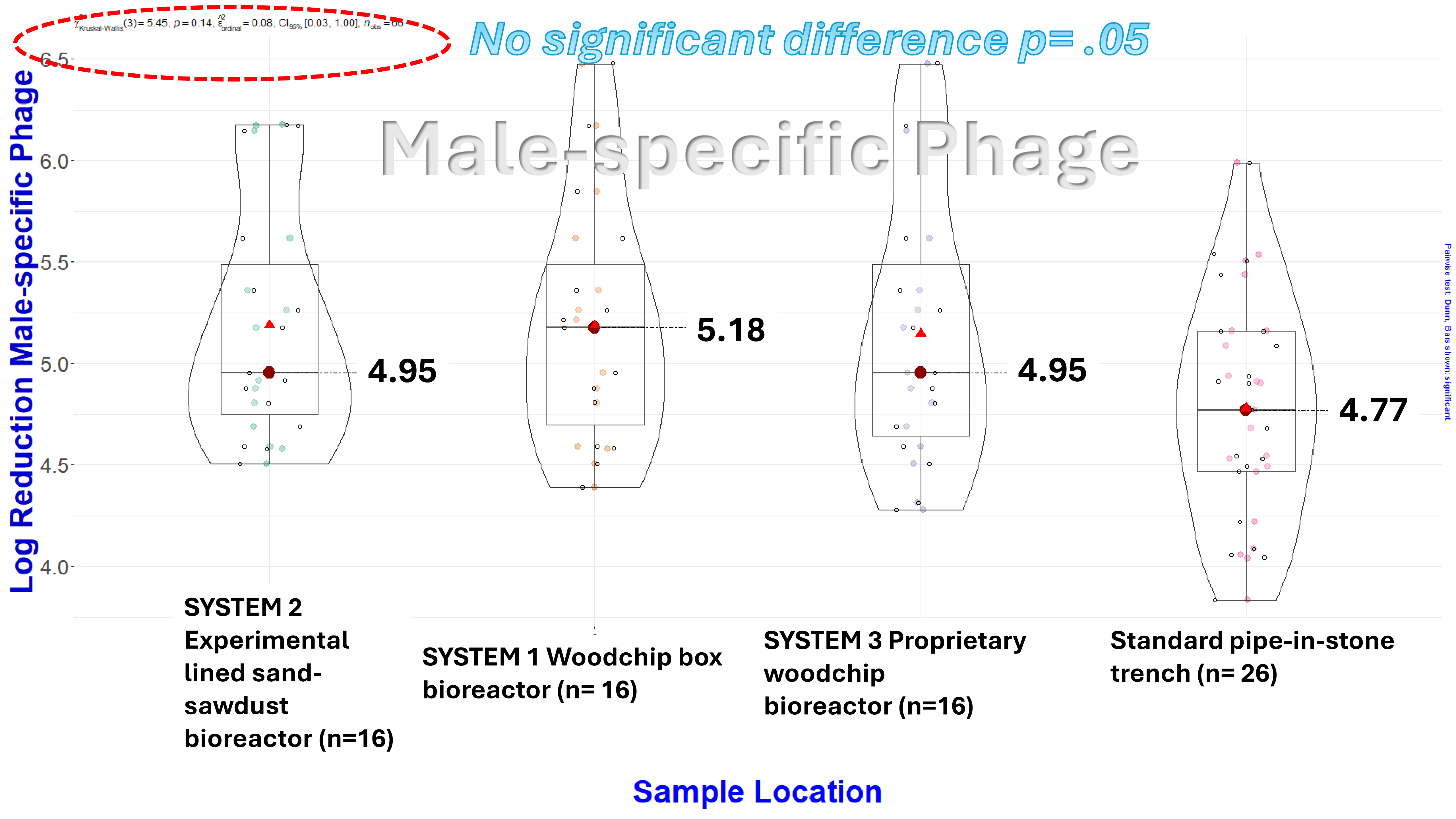
The challenge of viruses

They are

- Smaller (hence less filterable)
- Persistent (have no nutritional requirements)
- Pervasive
- Low infective doses

Male-specific and Somatic phage viruses are commonly used as surrogate measures for viruses of public health concern because of their size and culturability


χ²Kruskal-Wallis(3) = 14.39, p = 2.42e-03, ε²ordinal = 0.20, CI95% [0.09, 1.00], nobs = 73
pHolm-adj. = 9.82e-04
Somatic Phage
Log Reduction Somatic Phage
6
5
4
3
5.72
4.72
5.51
4.50
No significant difference
P= .05
Pairwise test: Dunn, Bars shown: significant
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=16)
SYSTEM 1 Woodchip box bioreactor (n= 16)
SYSTEM 3 Proprietary woodchip bioreactor (n=16)
Standard pipe-in-stone trench (n= 26)
Sample Location



$\chi^2_{\text{Kruskal-Wallis}}(3) = 5.45$, $p = 0.14$, $\hat{\varepsilon}^2_{\text{ordinal}} = 0.08$, $\text{CI}_{95\%}$ [0.03, 1.00], $n_{\text{obs}} = 66$
No significant difference p= .05
Male-specific Phage
Log Reduction Male-specific Phage
6.5
6.0
5.5
5.0
4.5
4.0
4.95
5.18
4.95
4.77
Pairwise test: Dunn, Bars shown: significant
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=16)
SYSTEM 1 Woodchip box bioreactor (n= 16)
SYSTEM 3 Proprietary woodchip bioreactor (n=16)
Standard pipe-in-stone trench (n= 26)
Sample Location

Very limited Sampling

Pharmaceuticals and personal care products

Sulfamethoxazole -antibiotic

Acetaminophen (Tylenol® and others)

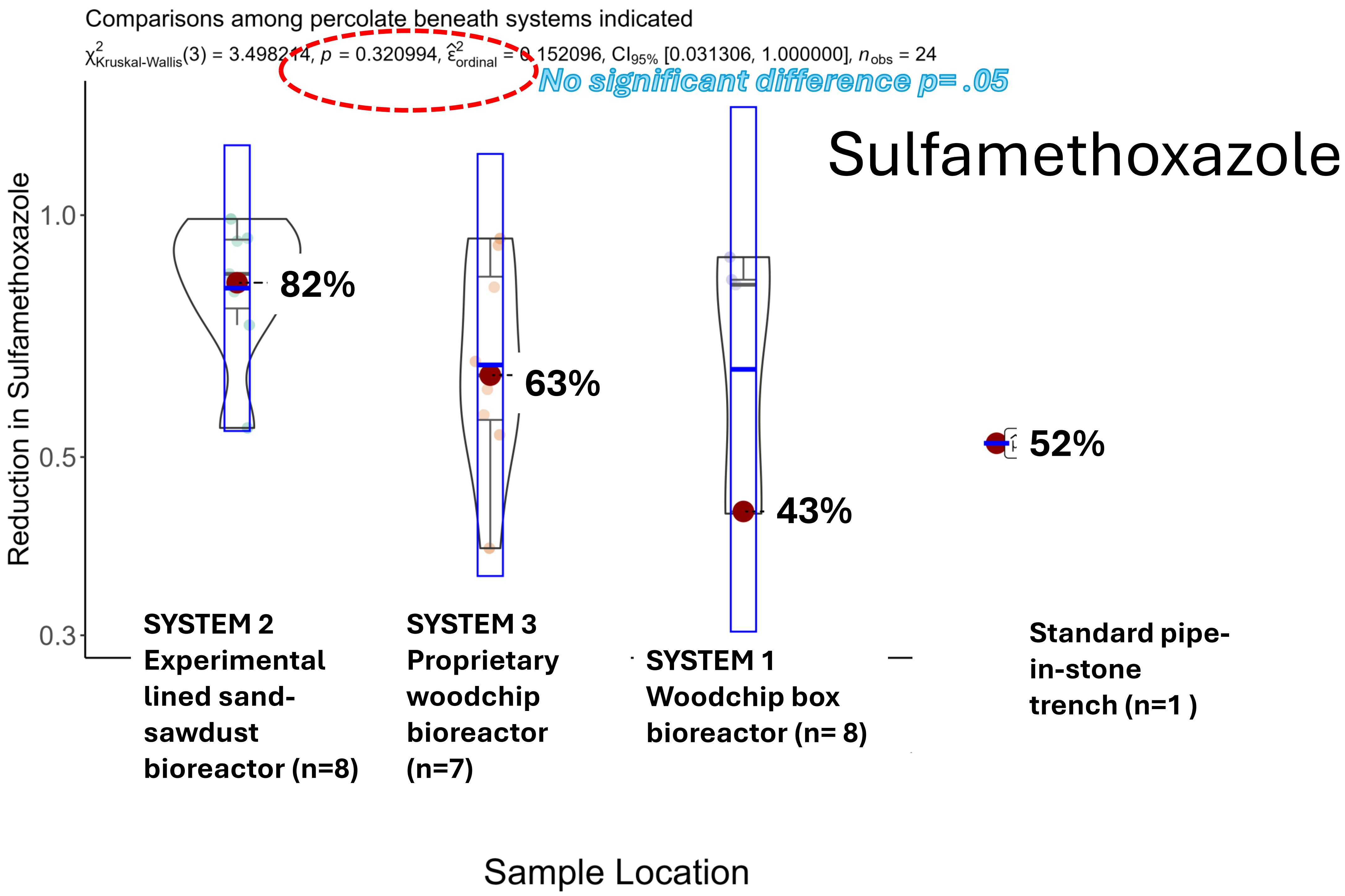
Ranitidine (histamine-2 blocker - Zantac® and others)

Carbamazepine used to treat certain types of seizures

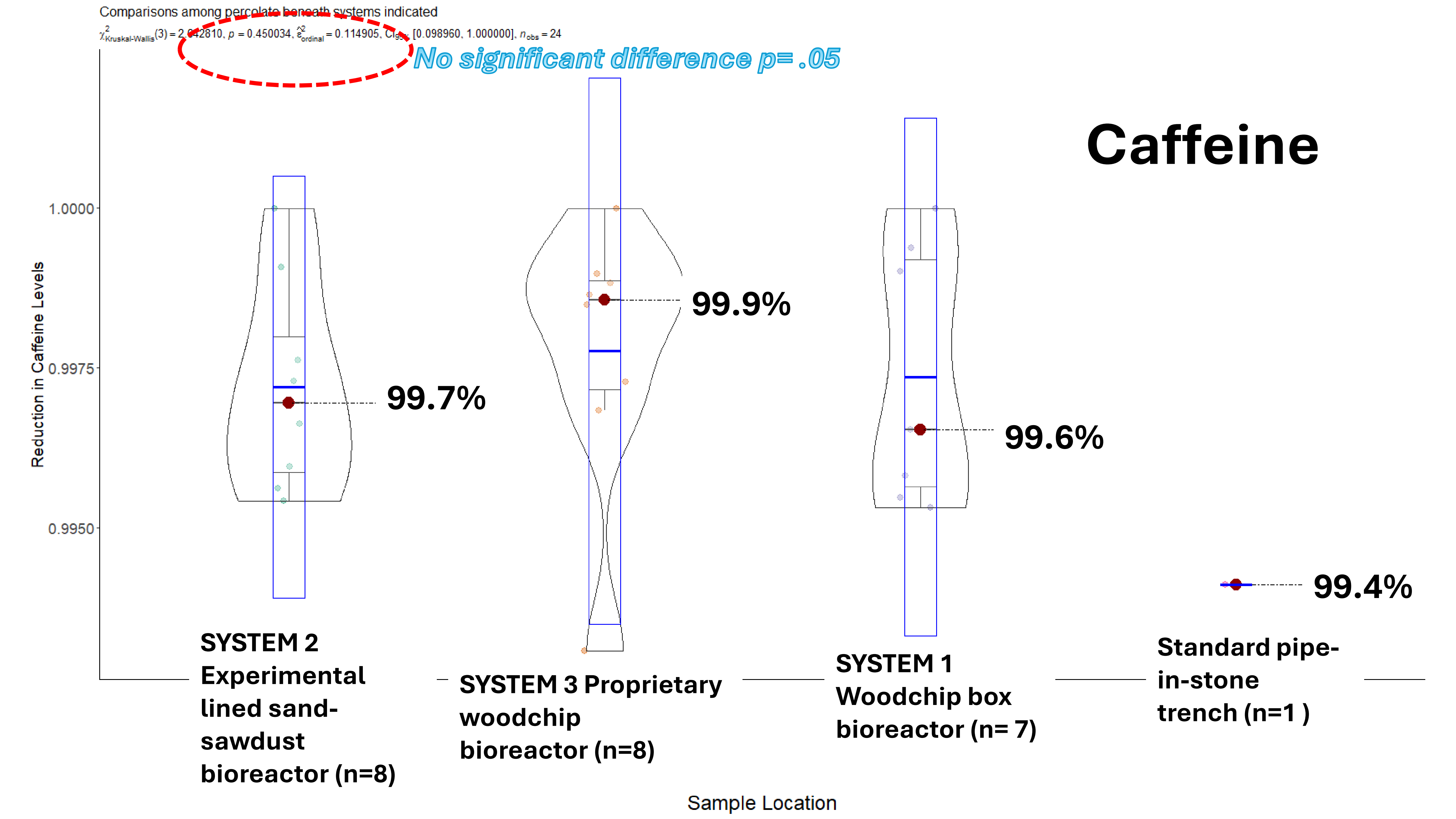
Atenolol – Blood pressure control

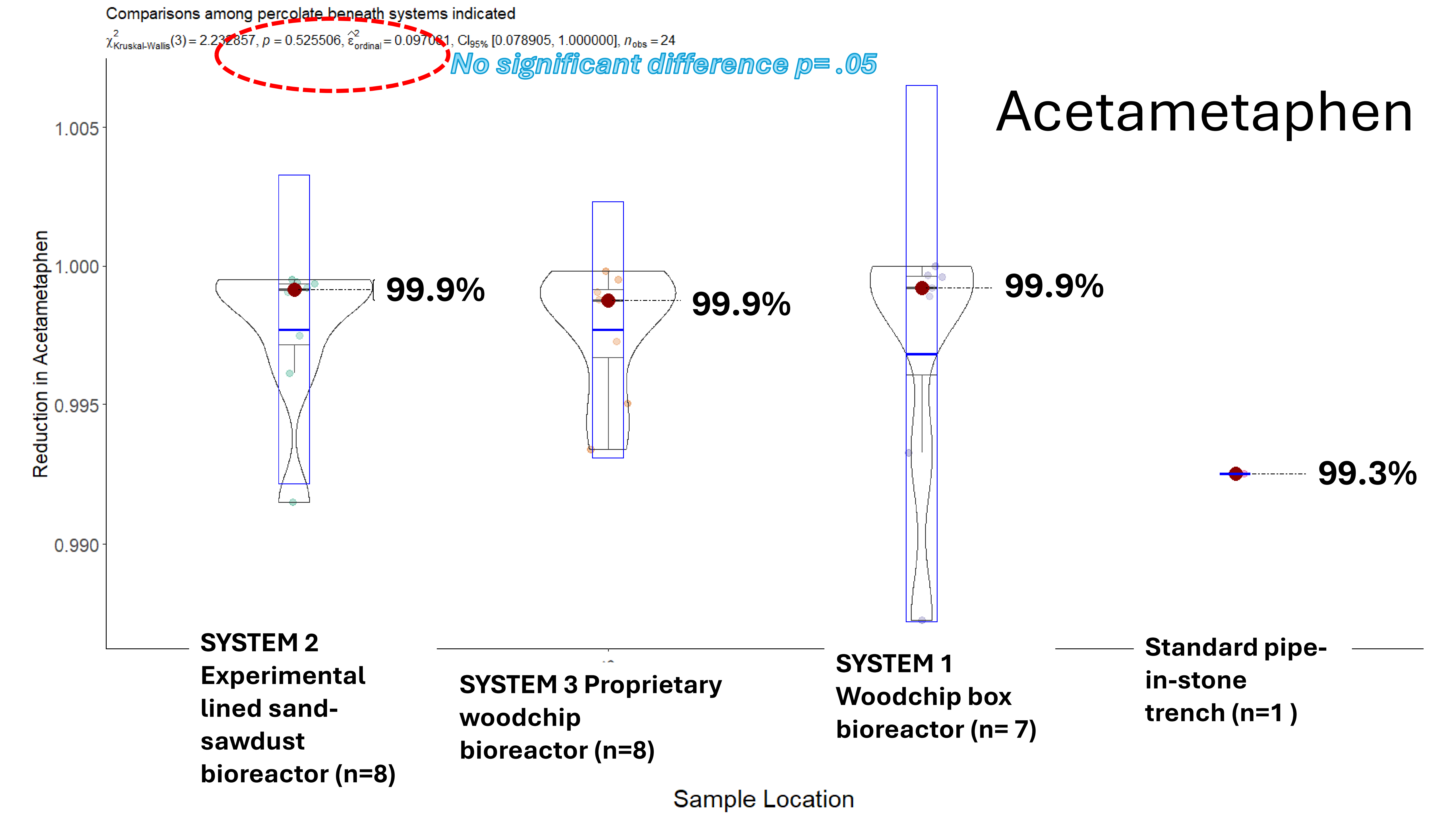
Caffeine – start your day medication

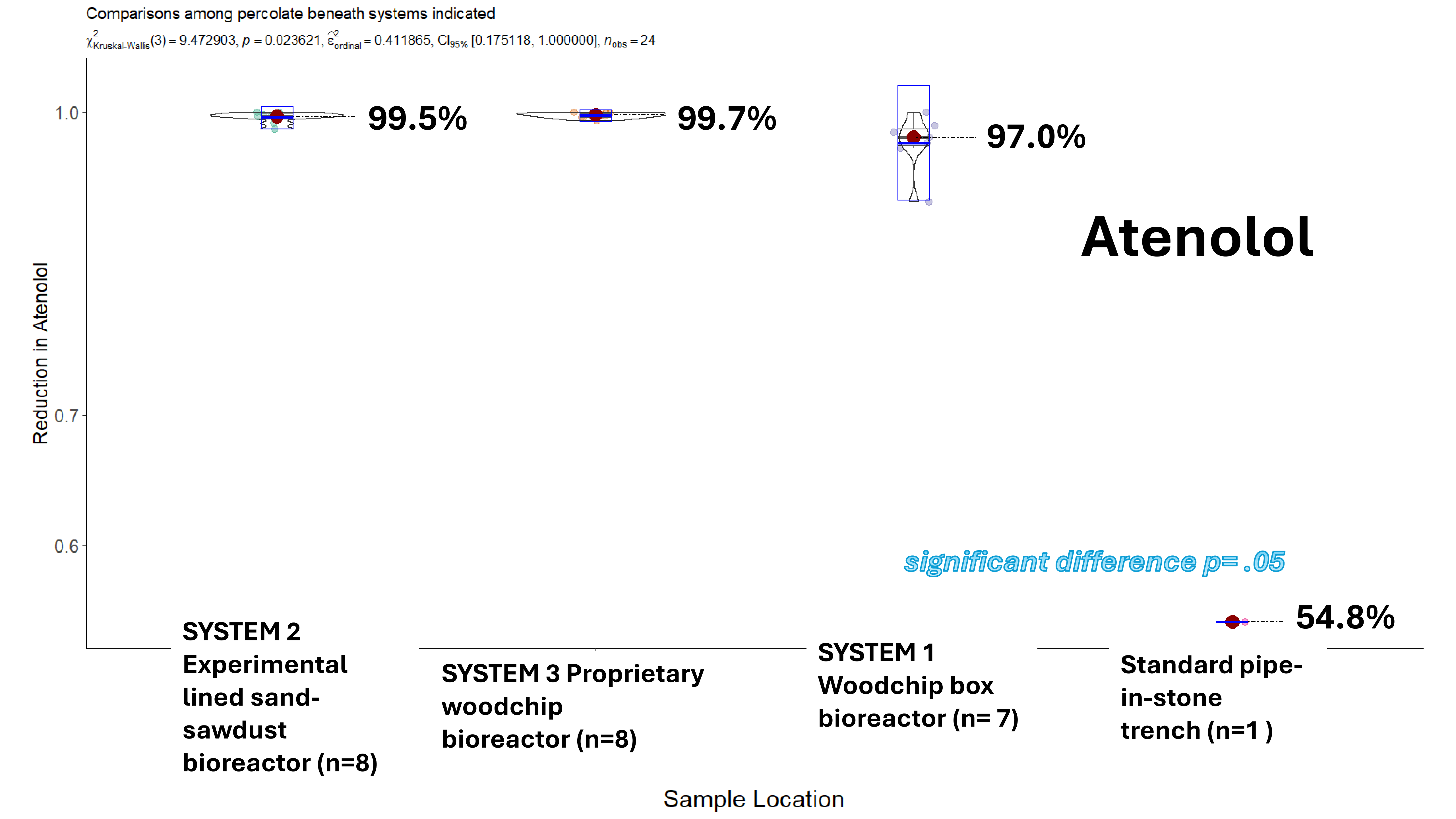
DEET - insect repellant



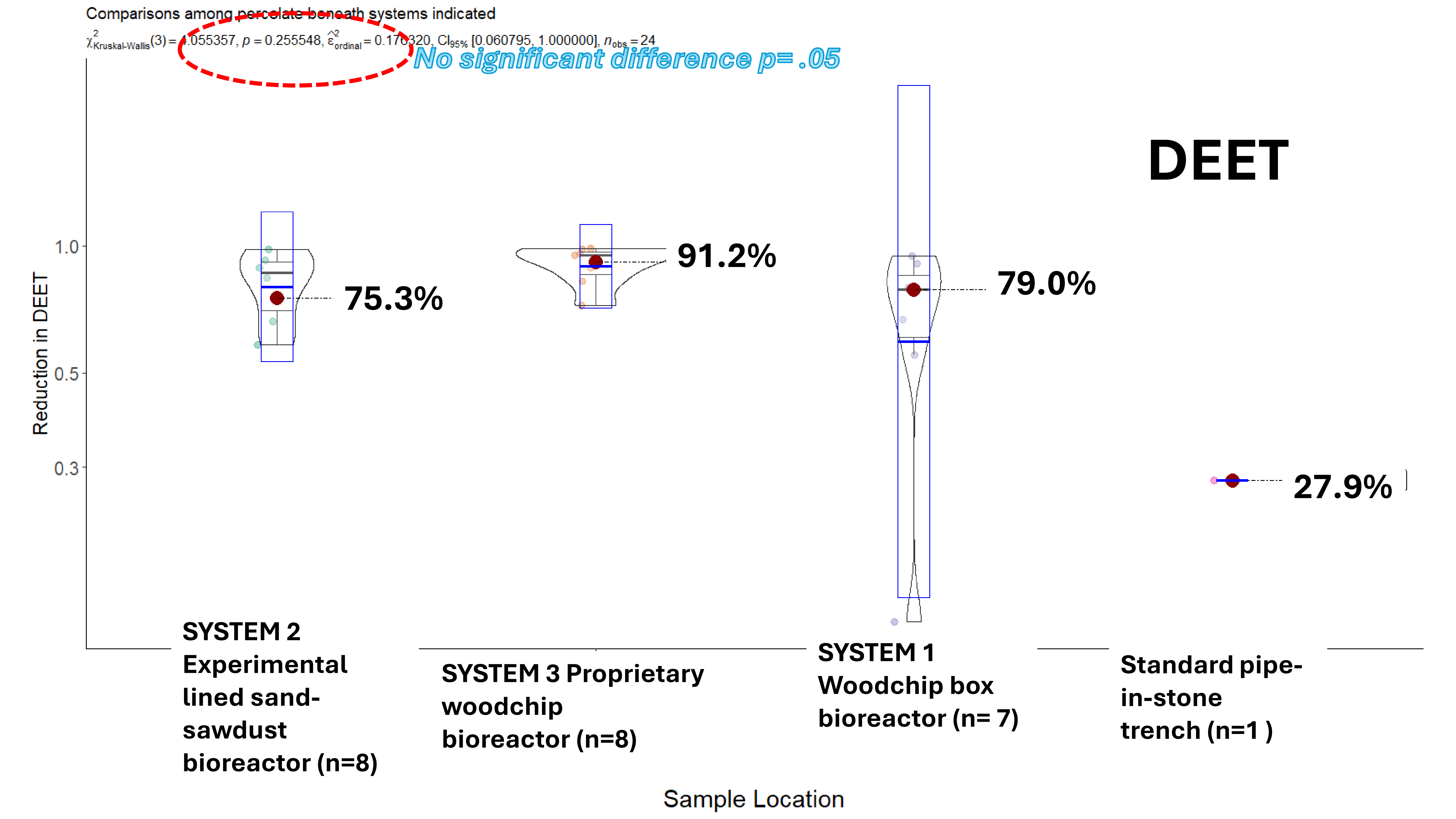
Comparisons among percolate beneath systems indicated
$\chi^2_{\text{Kruskal-Wallis}}(3) = 3.498214$, $p = 0.320994$, $\hat{\varepsilon}^2_{\text{ordinal}} = 0.152096$, $CI_{95\%}$ [0.031306, 1.000000], $n_{\text{obs}} = 24$
No significant difference p= .05
Sulfamethoxazole
Reduction in Sulfamethoxazole
1.0
0.5
0.3
82%
63%
43%
52%
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=8)
SYSTEM 3 Proprietary woodchip bioreactor (n=7)
SYSTEM 1 Woodchip box bioreactor (n= 8)
Standard pipe-in-stone trench (n=1)
Sample Location


Comparisons among percolate beneath systems indicated
$\chi^2_{Kruskal-Wallis}(3) = 2.642810$, $p = 0.450034$, $\hat{\epsilon}^2_{ordinal} = 0.114905$, $CI_{95\%}$ [0.098960, 1.000000], $n_{obs} = 24$
No significant difference p= .05
Caffeine
Reduction in Caffeine Levels
1.0000
0.9975
0.9950
99.7%
99.9%
99.6%
99.4%
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=8)
SYSTEM 3 Proprietary woodchip bioreactor (n=8)
SYSTEM 1 Woodchip box bioreactor (n= 7)
Standard pipe-in-stone trench (n=1)
Sample Location

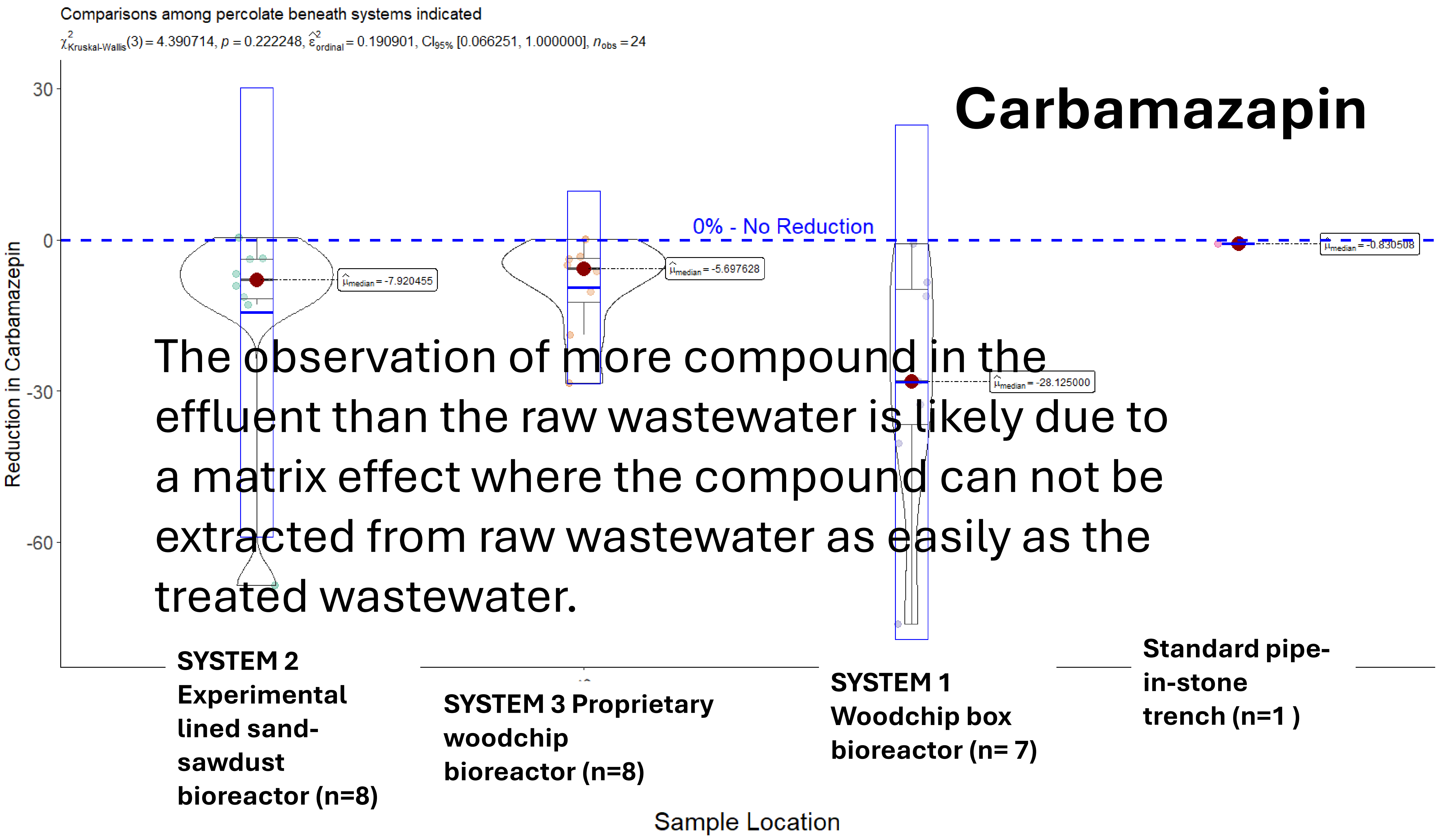

Comparisons among percolate beneath systems indicated
$\chi^2_{Kruskal-Wallis}(3) = 2.232857$, $p = 0.525506$, $\hat{\varepsilon}^2_{ordinal} = 0.097081$, $CI_{95\%}$ [0.078905, 1.000000], $n_{obs} = 24$
No significant difference p= .05
Acetametaphen
Reduction in Acetametaphen
1.005
1.000
0.995
0.990
99.9%
99.9%
99.9%
99.3%
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=8)
SYSTEM 3 Proprietary woodchip bioreactor (n=8)
SYSTEM 1 Woodchip box bioreactor (n= 7)
Standard pipe-in-stone trench (n=1)
Sample Location

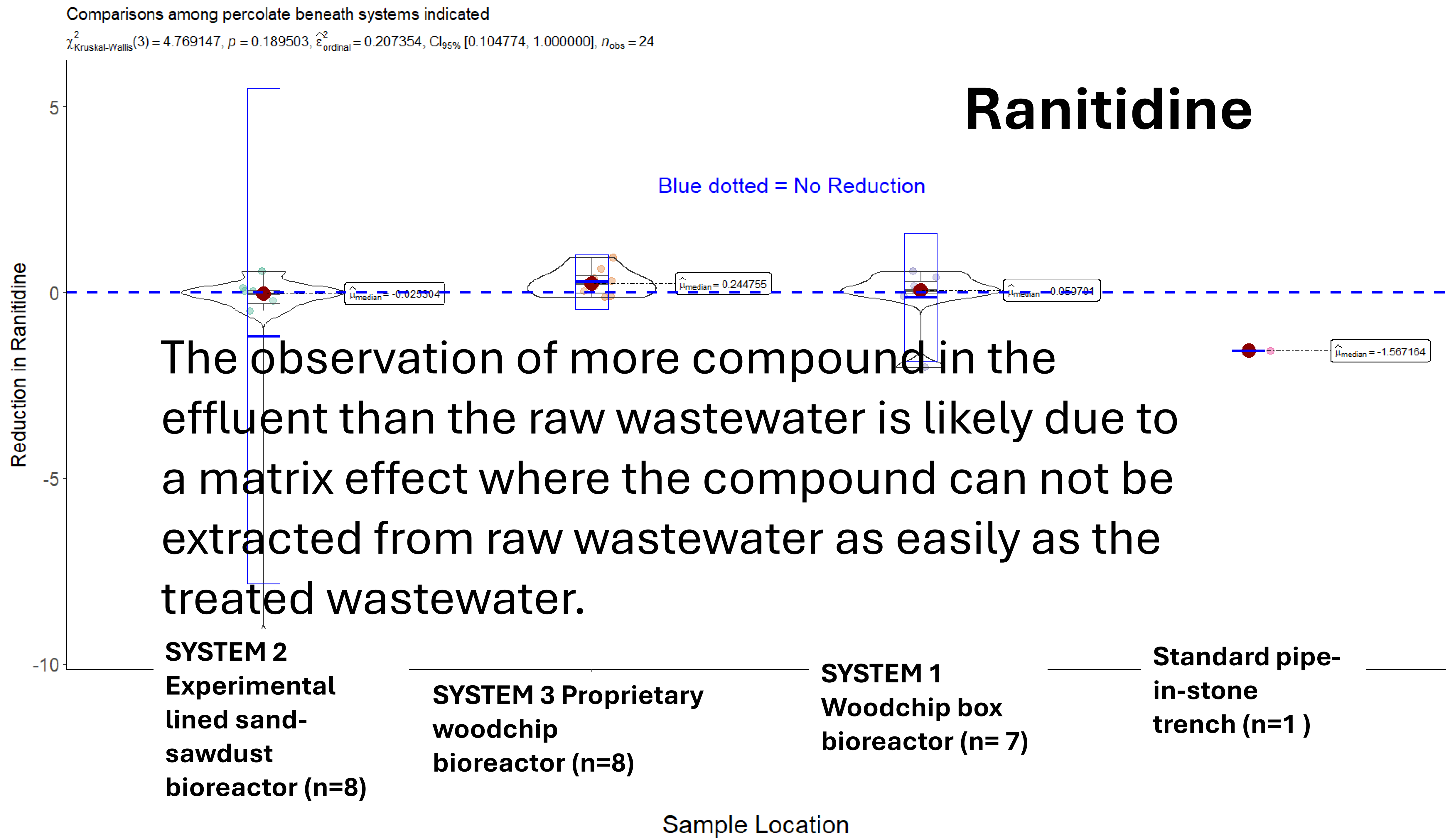


Comparisons among percolate beneath systems indicated
$\chi^2_{Kruskal\text{-}Wallis}(3) = 9.472903$, $p = 0.023621$, $\hat{\varepsilon}^2_{ordinal} = 0.411865$, $CI_{95\%}$ [0.175118, 1.000000], $n_{obs} = 24$
Reduction in Atenolol
1.0
0.7
0.6
99.5%
99.7%
97.0%
54.8%
Atenolol
significant difference p= .05
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=8)
SYSTEM 3 Proprietary woodchip bioreactor (n=8)
SYSTEM 1 Woodchip box bioreactor (n= 7)
Standard pipe-in-stone trench (n=1)
Sample Location



Comparisons among percolate beneath systems indicated
$\chi^2_{\text{Kruskal-Wallis}}(3) = 4.055357$, $p = 0.255548$, $\hat{\varepsilon}^2_{\text{ordinal}} = 0.176320$, $\text{CI}_{95\%}$ [0.060795, 1.000000], $n_{\text{obs}} = 24$
No significant difference p= .05
DEET
Reduction in DEET
1.0
0.5
0.3
75.3%
91.2%
79.0%
27.9%
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=8)
SYSTEM 3 Proprietary woodchip bioreactor (n=8)
SYSTEM 1 Woodchip box bioreactor (n= 7)
Standard pipe-in-stone trench (n=1)
Sample Location

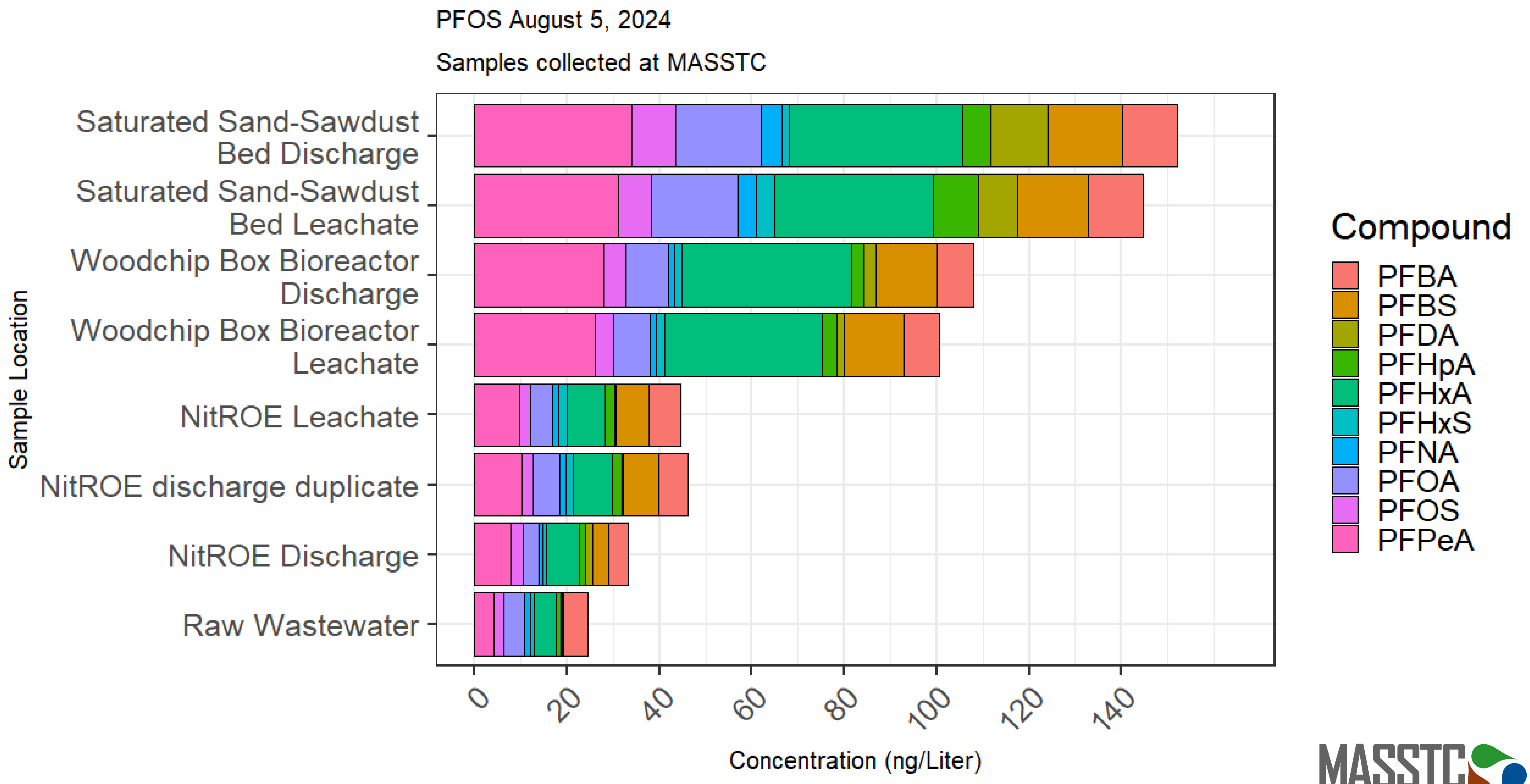

Comparisons among percolate beneath systems indicated
$\chi^2_{\text{Kruskal-Wallis}}(3) = 4.390714$, $p = 0.222248$, $\hat{\varepsilon}^2_{\text{ordinal}} = 0.190901$, $\text{CI}_{95\%}$ [0.066251, 1.000000], $n_{\text{obs}} = 24$
Carbamazapin
0% - No Reduction
$\hat{\mu}_{\text{median}} = -7.920455$
$\hat{\mu}_{\text{median}} = -5.697628$
$\hat{\mu}_{\text{median}} = -28.125000$
$\hat{\mu}_{\text{median}} = -0.830508$
The observation of more compound in the effluent than the raw wastewater is likely due to a matrix effect where the compound can not be extracted from raw wastewater as easily as the treated wastewater.
Reduction in Carbamazepin
30
0
-30
-60
SYSTEM 2 Experimental lined sand-sawdust bioreactor (n=8)
SYSTEM 3 Proprietary woodchip bioreactor (n=8)
SYSTEM 1 Woodchip box bioreactor (n= 7)
Standard pipe-in-stone trench (n=1)
Sample Location



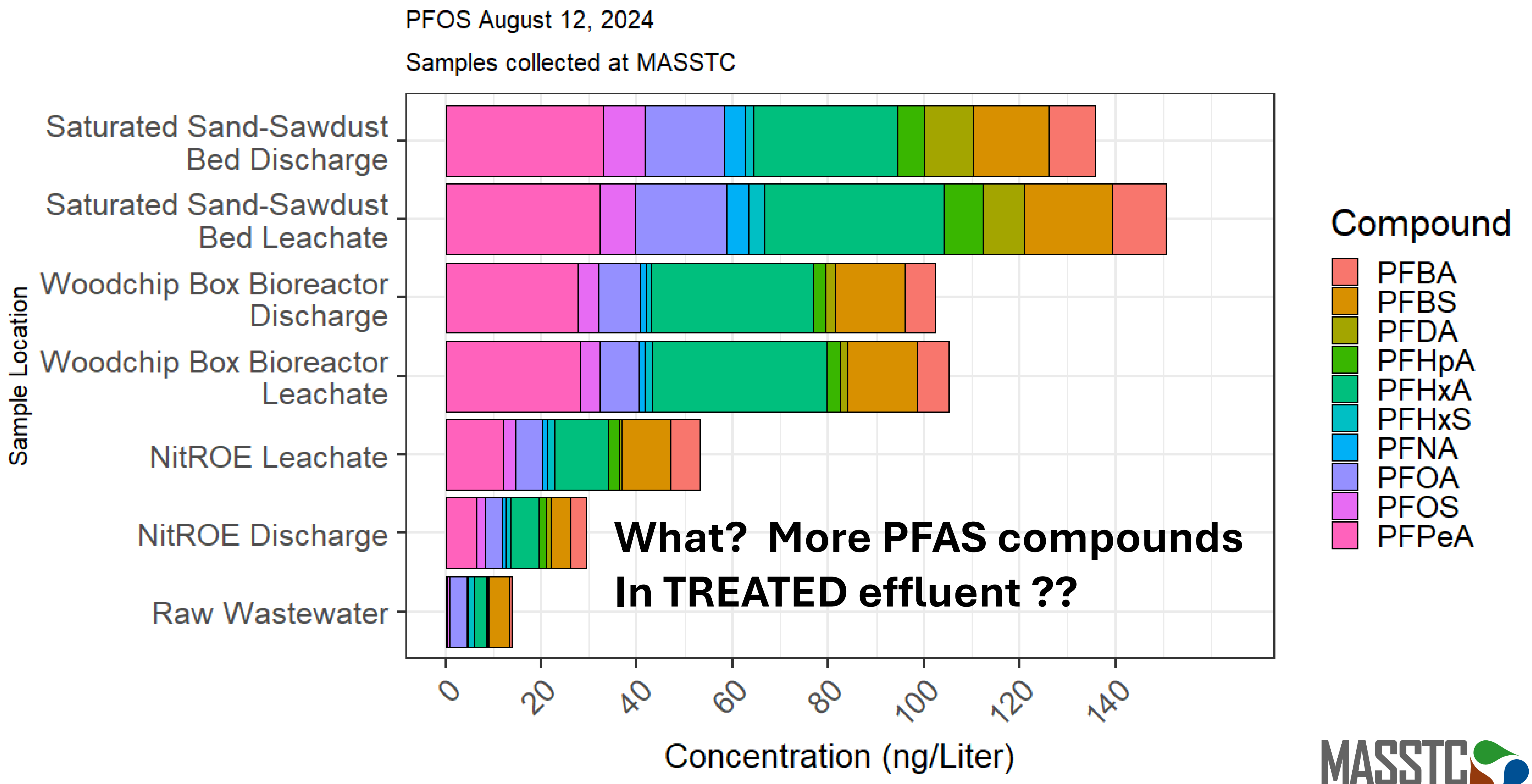
Ranitidine

The observation of more compound in the effluent than the raw wastewater is likely due to a matrix effect where the compound can not be extracted from raw wastewater as easily as the treated wastewater.

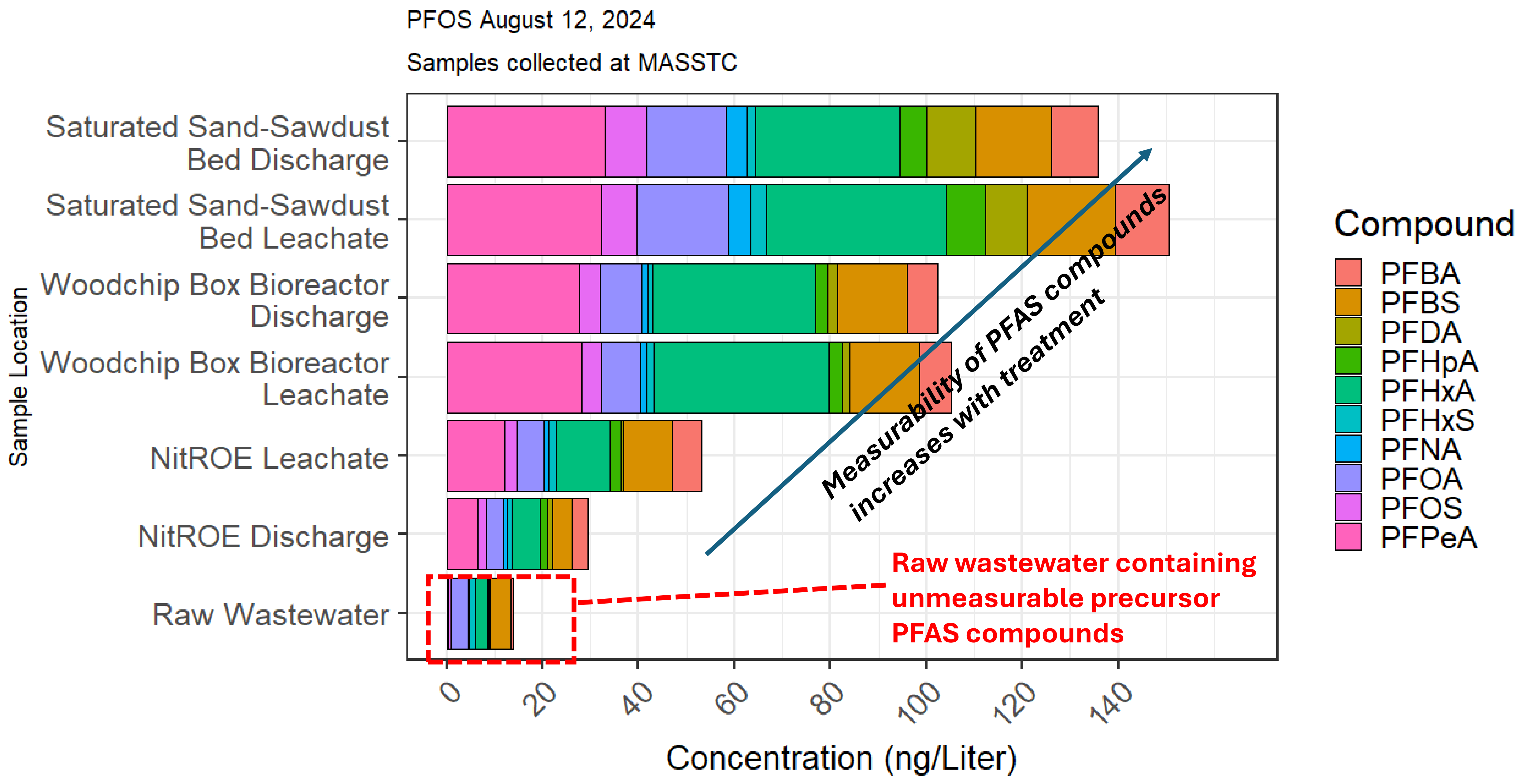
PFOS – the rabbit holes of all rabbit holes



MASSTC
The Massachusetts Alternative Septic System Test Center



MASSTC
The Massachusetts Alternative Septic System Test Center


PFOS August 12, 2024
Samples collected at MASSTC
Sample Location
Saturated Sand-Sawdust Bed Discharge
Saturated Sand-Sawdust Bed Leachate
Woodchip Box Bioreactor Discharge
Woodchip Box Bioreactor Leachate
NitROE Leachate
NitROE Discharge
Raw Wastewater
0
20
40
60
80
100
120
140
Concentration (ng/Liter)
Compound
PFBA
PFBS
PFDA
PFHpA
PFHxA
PFHxS
PFNA
PFOA
PFOS
PFPeA
Measurability of PFAS compounds increases with treatment
Raw wastewater containing unmeasurable precursor PFAS compounds

What about Ponding ?

Over 15 months, no ponding of effluent inside the leaching components has been observed

Conclusions

- **Leaching pits or other open structures hydraulically loaded (HLR) at previously-allowed rates and receiving treated effluent from cellulose-based denitrification systems appear to offer similar treatment for biological indicators as presently allowed structures receiving septic tank effluent.**
- **Although sampling for Contaminants of Emerging Concern was limited, in no case was the leachate beneath the higher HLR leach structures less efficient at removing the organic compound than standard allowed trenches.**
- **Results for perfluorinated alkylated substances (PFAS) compounds indicated higher levels of PFAS in treated wastewater similar to other work not reported here. Although more work needs to be done, it appears that unmeasurable (by method) precursor PFAS compounds are converted to measurable compounds during the treatment process.**
- **If the previously allowed hydraulic loading rates could be allowed, it will result in significant savings of costs and space which could incentivize the placement of Best Available Technology for nitrogen removal while offering adequate public health and environmental protection.**

Of course (future research)

- More research needs to be done regarding contaminants of emerging concern to include endocrine disrupting compounds.
- A more robust comparison with standard practices needs to be made (certainly more than one measurement).
- The present study needs to be continued to the point that it could predict time of “failure” for the highly-loaded open structure.
- Donations to the above collected as you leave the room.


Thank you
Questions?
MASSTC
The Massachusetts Alternative Septic System Test Center
"Write the bad things done to you in the sand and the good things on a piece of granite" (old Arabic saying)
Watch this space