Virus considerations in septic system design and wastewater reuse options – what you should know

Just when you think you could put the subject behind you

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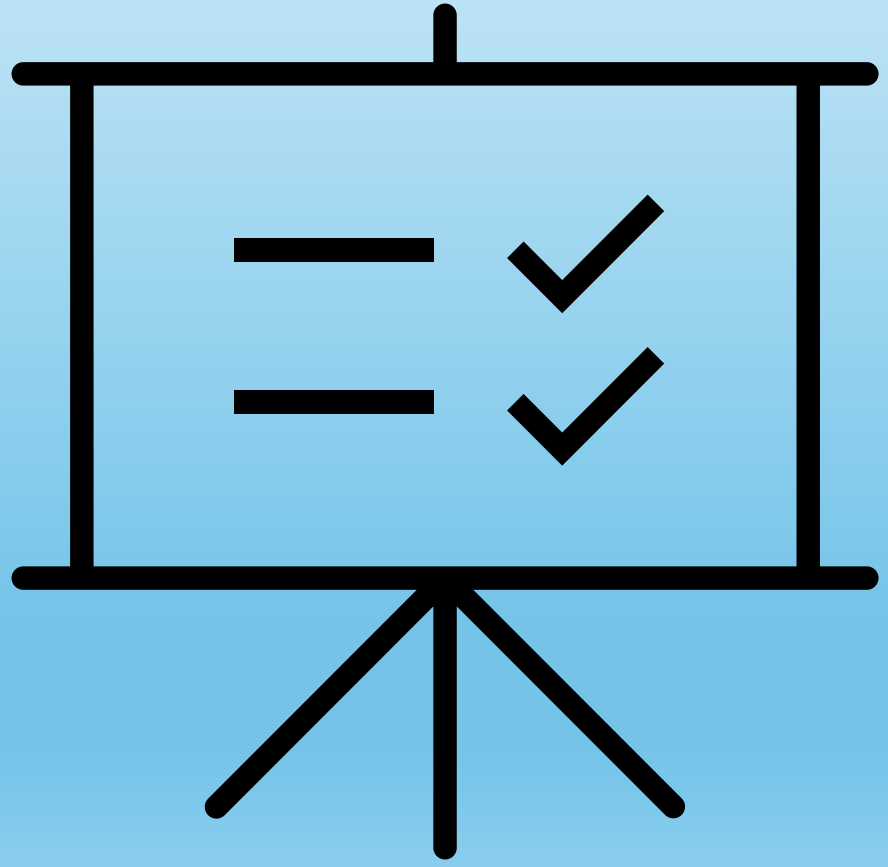
Environmental Specialist

MASSTC
The Massachusetts Alternative
Septic System Technology Center

Session Goals

- Review - why we care about viruses in wastewater
- Detection of viruses in the environment
- Routes of exposure relevant to septic systems
- Assessing the risk from human pathogens – what are the tools?
- Project overview of two projects that MASSTC is involved with
- Future directions



Viruses – why we care

Viruses are…

- Small
- Many (over 150 human viruses)
- Pervasive
- Infective/invasive

Viruses are NOT

- Cute
- Something you want to underestimate

Picornaviridae (poliovirus, enterovirus, coxsackievirus, hepatitis A virus, and echovirus), Caliciviridae (norovirus, calicivirus, astrovirus, and sapovirus), Reoviridae (reovirus and rotavirus), Adenoviridae (adenovirus), and Coronaviridae (coronavirus). – ***to name a few***

How small?

One 200 nanometer virus 

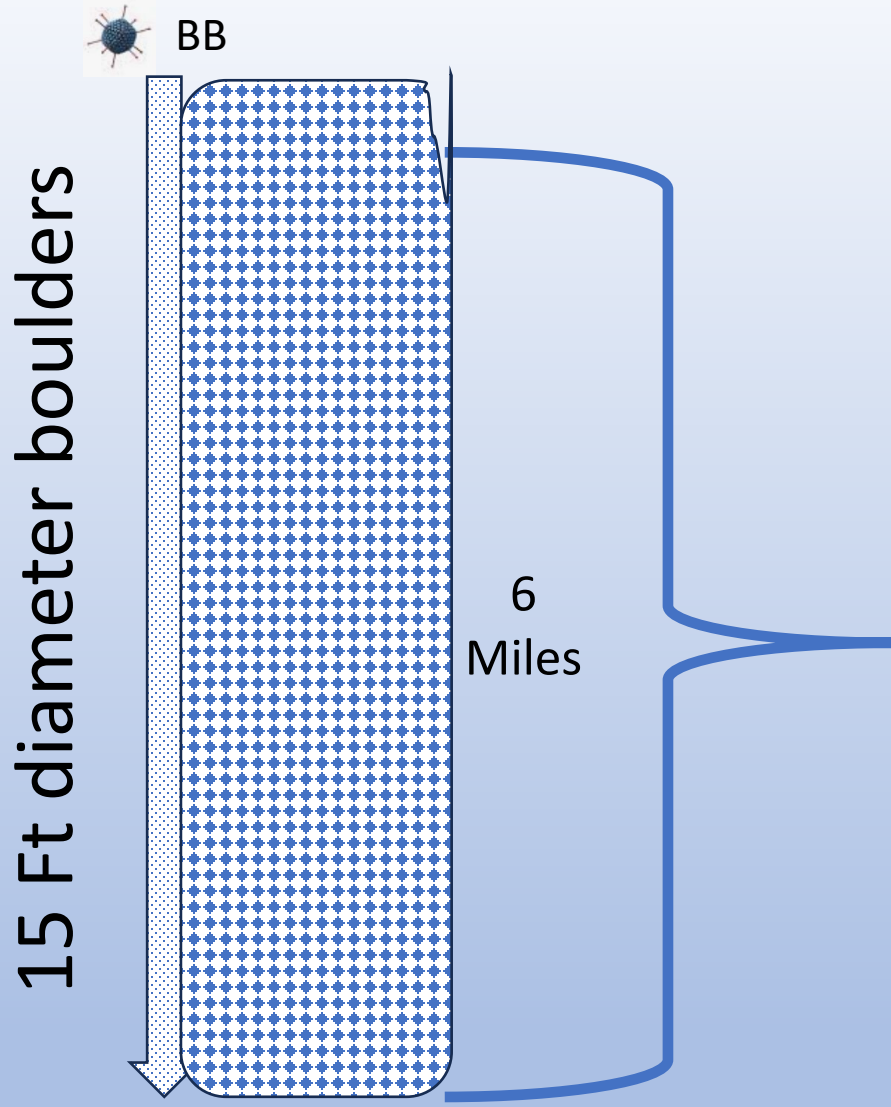
x 23,000 magnification

One 0.2-millimeter grain of sand

x 23,000 magnification

15 feet

Another perspective

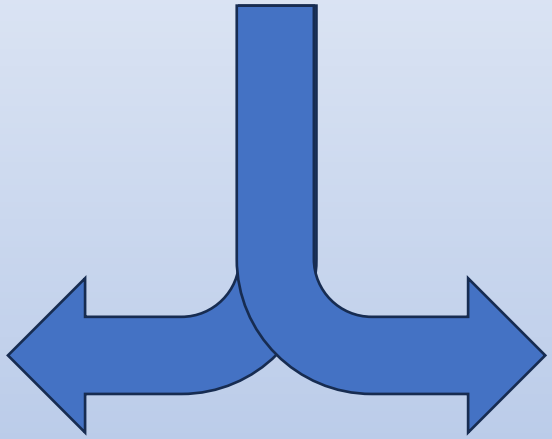


A four -foot vertical separation to groundwater relative to viruses is like passing a BB-sized particle through a leachfield containing boulders of 15-ft diameter and 6 miles deep

Detection of viruses in the environment

Culture and count

The vast number of human viruses are not culturable in a laboratory setting



Polymerase chain reaction PCR

PCR and specifically ddPCR is the most prominent method for detecting virus components in the environmental setting.

Culture and count

While we cannot culture human viruses from the environment, we can (and do) culture virus surrogates which are indicators of the potential presence of human viruses.

Coliphage or “phage” – culturable, generally harmless indicators of wastewater and hence potential presence of human viruses.

Coliphage

If you think it's just a phage you're going through……..

It's more likely a phage going through **you**

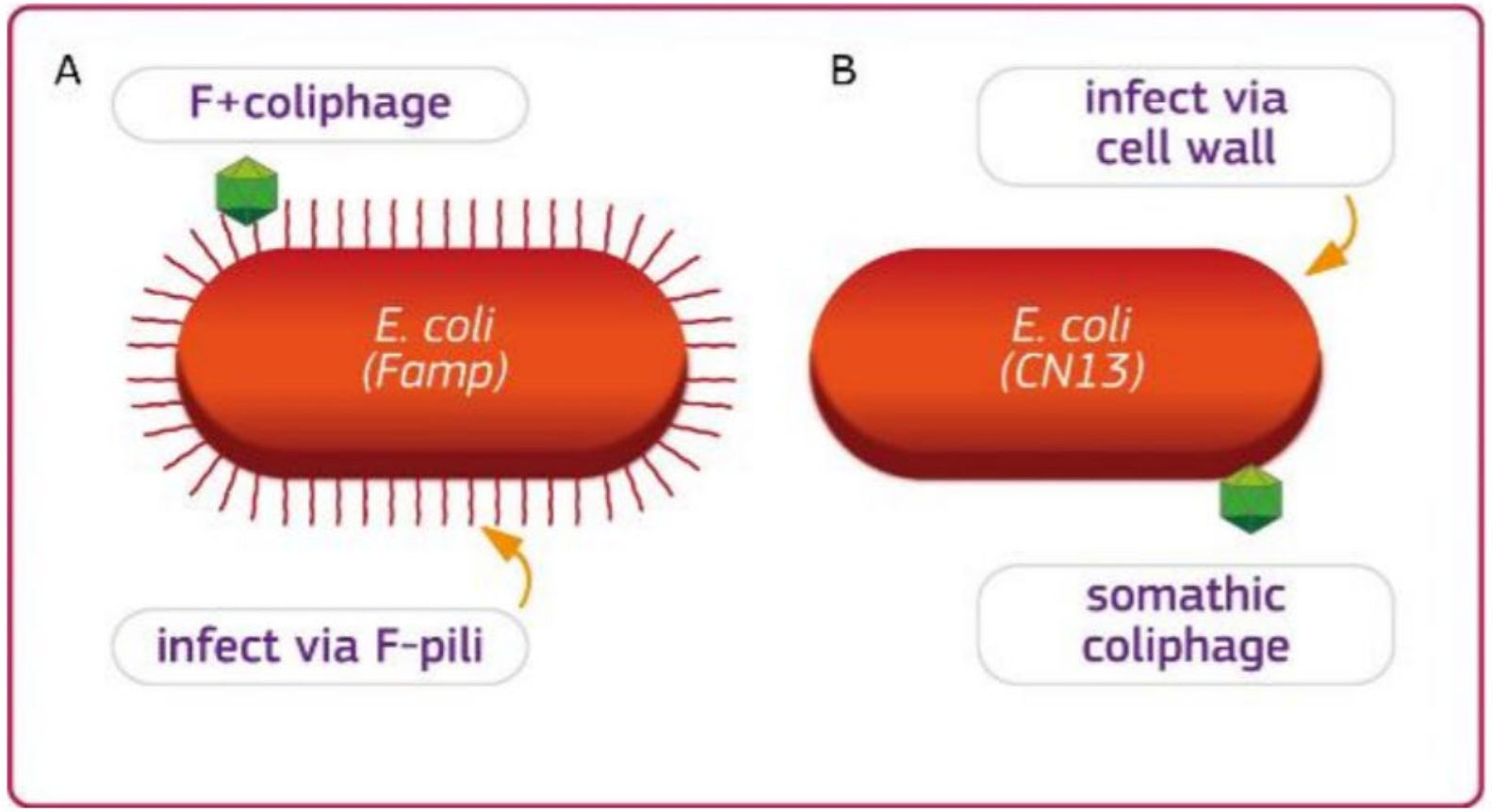
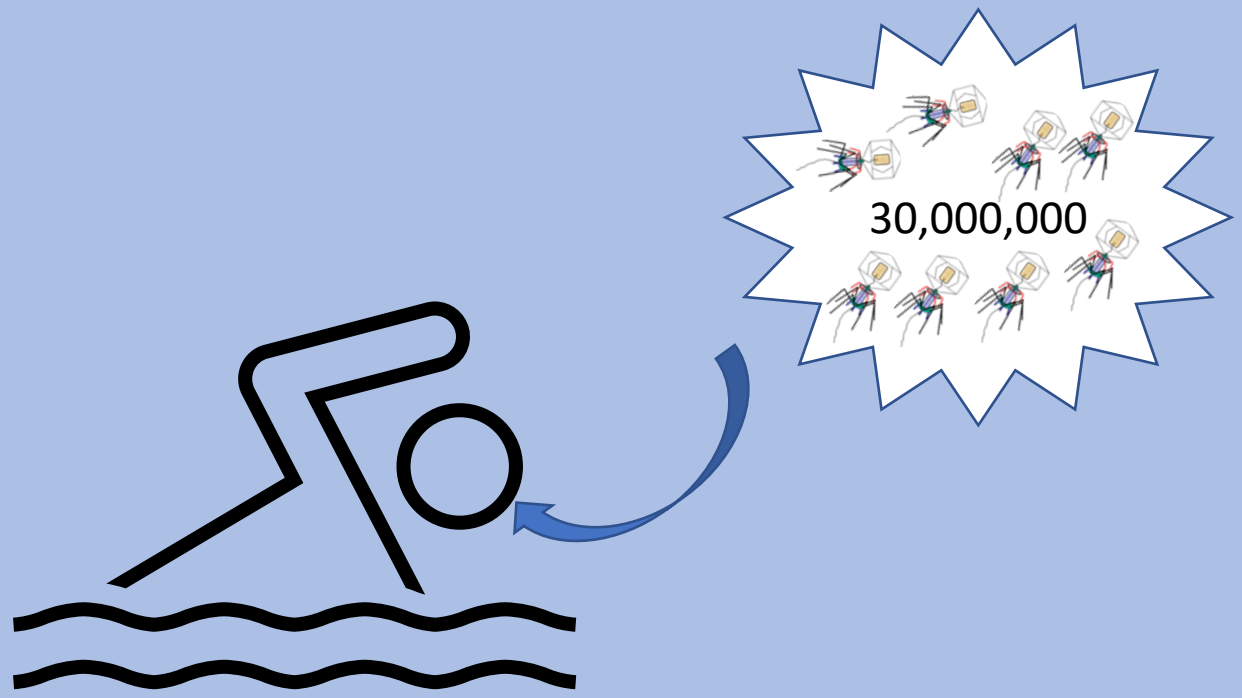


Figure 5. Schematic representation of F-specific (or male-specific) coliphages, somatic coliphages and their host cells. (A) F-specific coliphages infect host cells (e.g. *E. coli* Famp, *Salmonella typhimurium* WG49) through the sex pili encoded by the F-plasmid. (B) Host strains of somatic coliphages include *E. coli* (e.g. *E. coli* CN13) and related species which are infected through the cell wall.

Source: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118219/final_jrc_tech_report_dwd___06.04.20_final_pdf%284%29.pdf

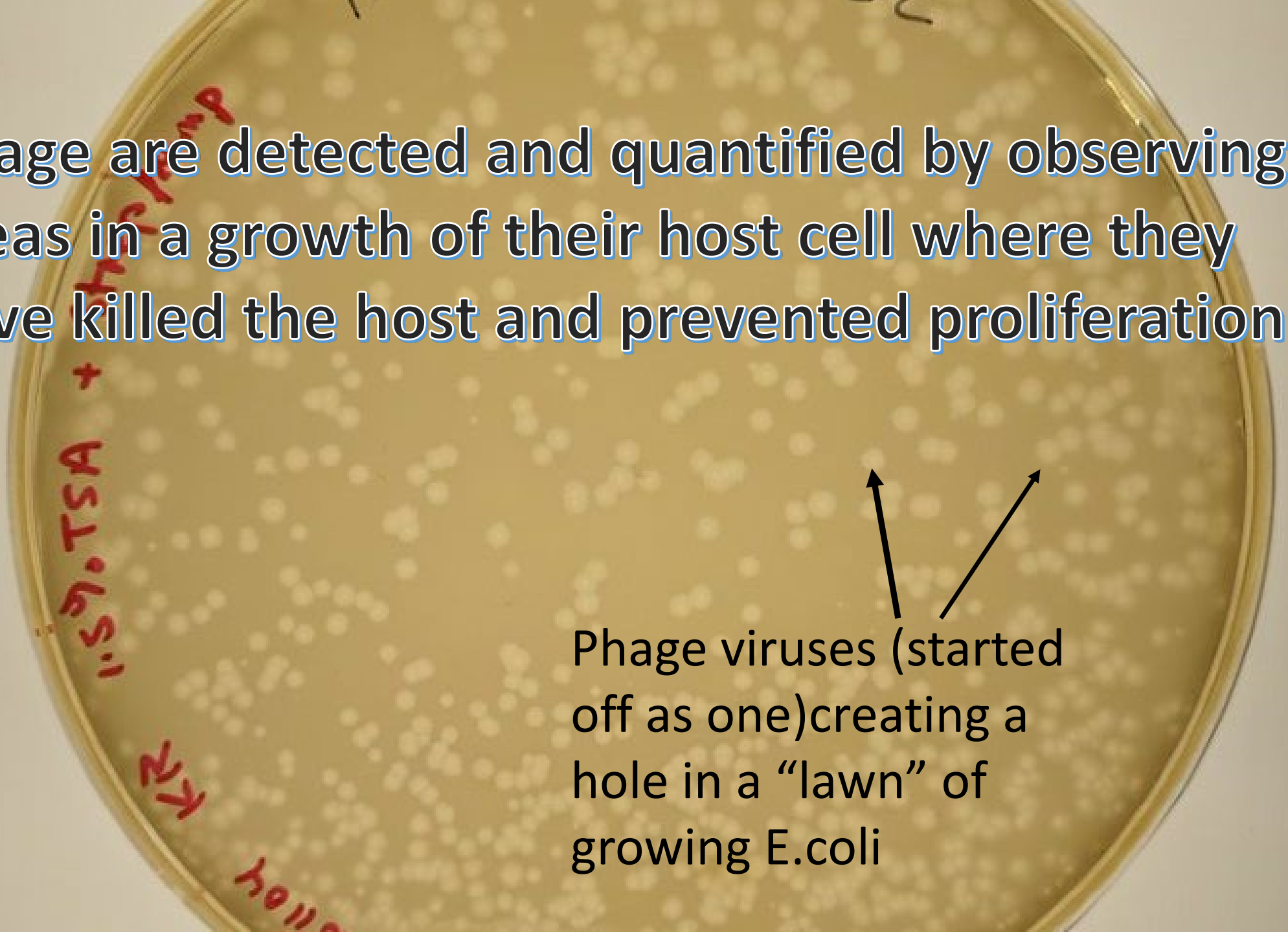
On a side note♪ phage have been used in medical therapy to destroy bacterial pathogens in the human infections.

Interesting factoid



When swimming in the ocean, it's just the phage you're going through ☺

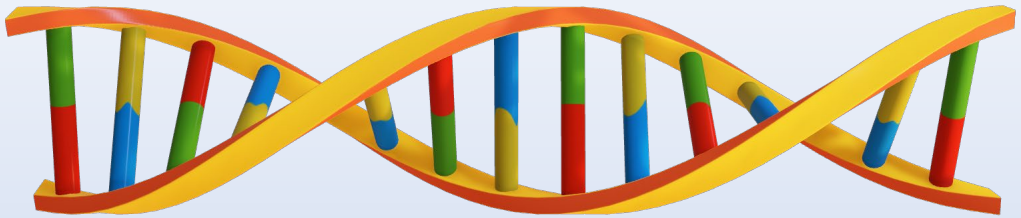
Phage are detected and quantified by observing areas in a growth of their host cell where they have killed the host and prevented proliferation



Phage viruses (started off as one)creating a hole in a “lawn” of growing E.coli

ANALOGY

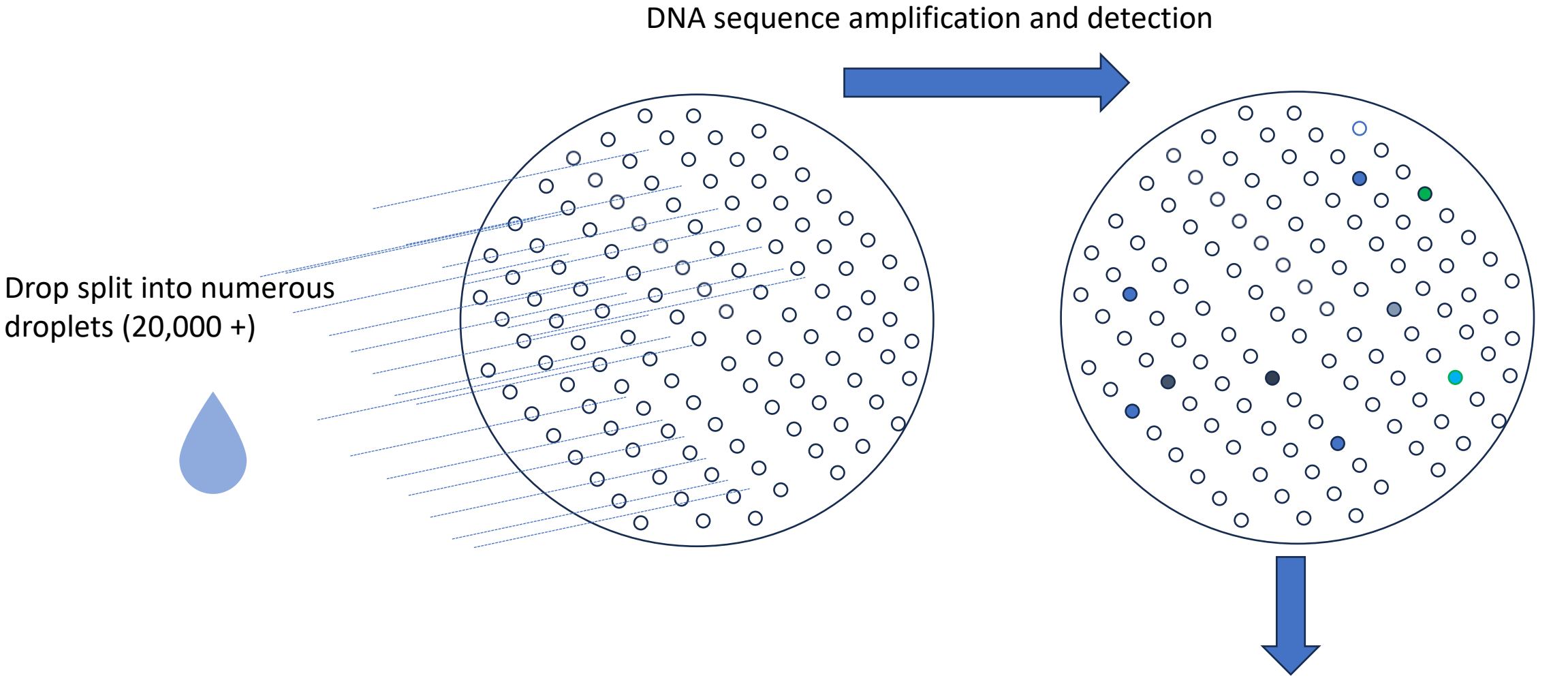
PCR



and specifically

ddPCR

Droplet digital PCR (ddPCR) – a game changer for both low level viral particle detection and accuracy.



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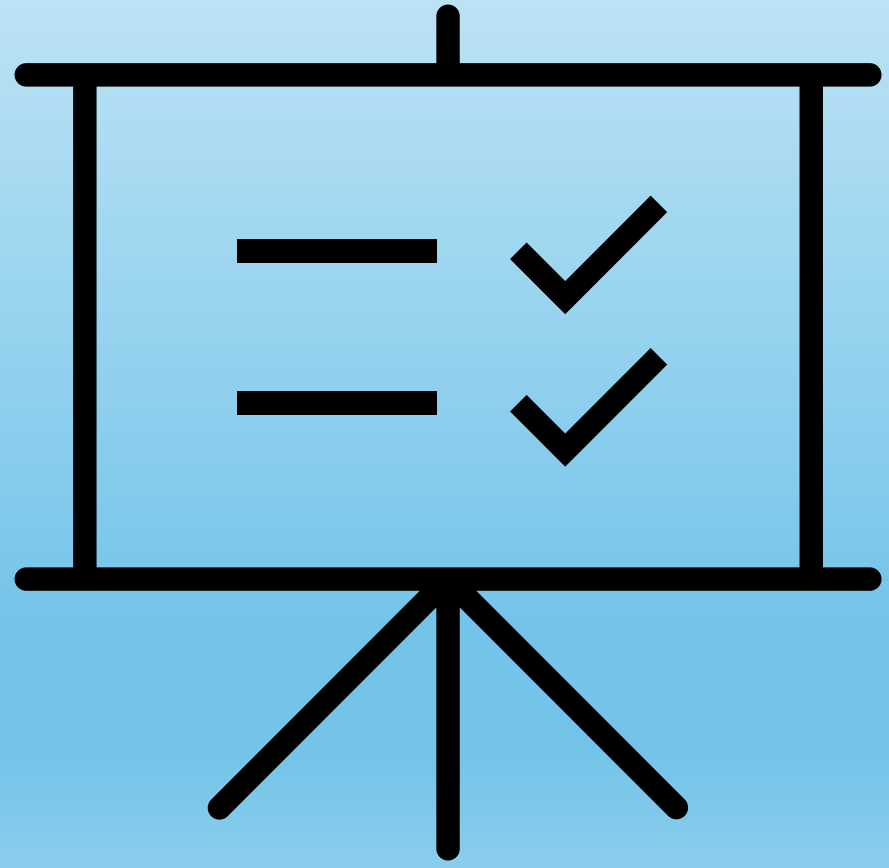
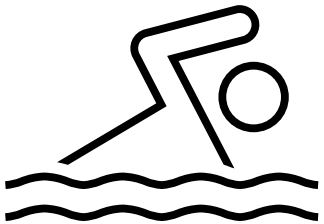
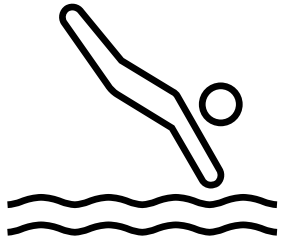


Once upon a time, in a groundwater far away….

From here……

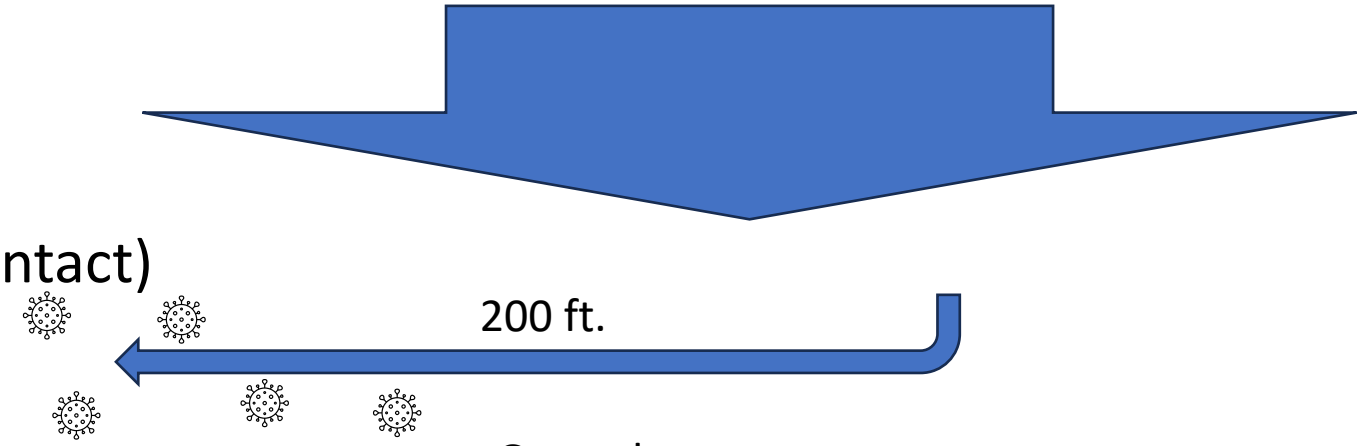


…..to there



Potential pathways for human exposure

Bathing beach (recreational contact)
Groundwater expressions (incidental contact)
Shellfish areas (concentrated ingestion)
Drinking water wells (ingestion)
Irrigation wells (airborne mist – respiratory and ingestion)



Entrainment of Viruses from Septic Tank Leach Fields Through a Shallow, Sandy Soil Aquifer

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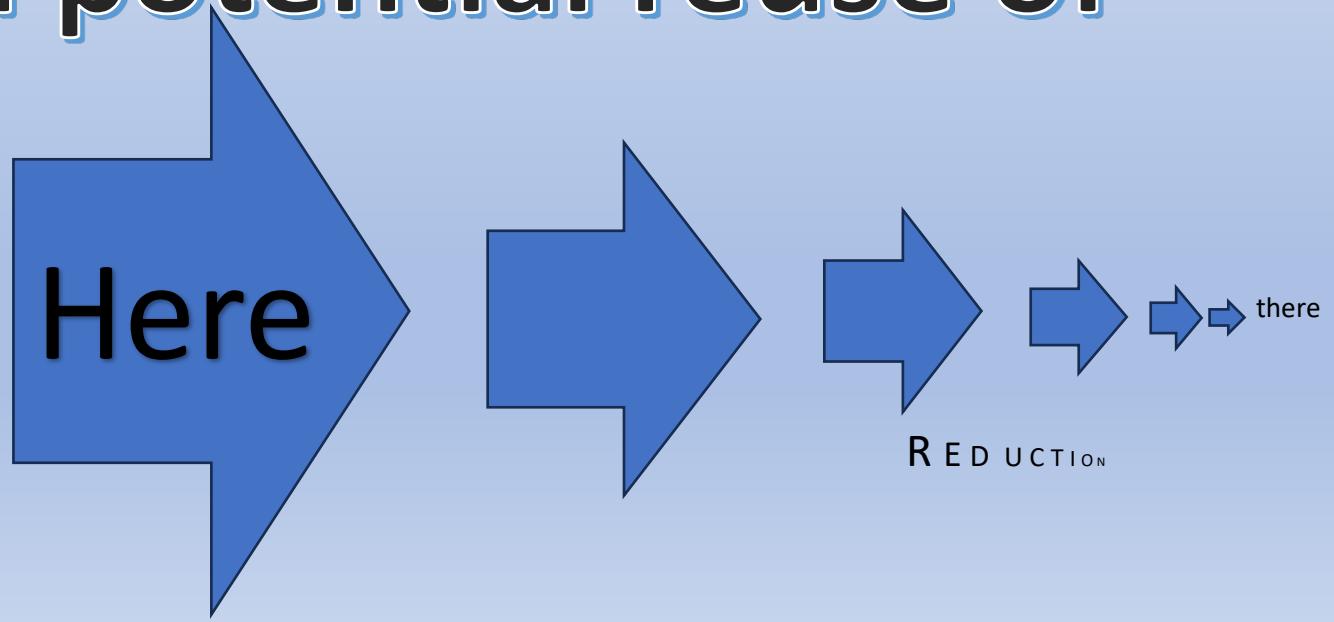
Department of Energy and Environment, Brookhaven National Laboratory, Upton, New York 11973

Received 17 November 1982/Accepted 8 March 1983

PART 2

Assessing the risk of septic systems and potential reuse of wastewater



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.

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

A brief lesson in log reduction

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.

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

Informal target Title 5 before groundwater contact

WHO for unrestricted irrigation

California for direct reuse

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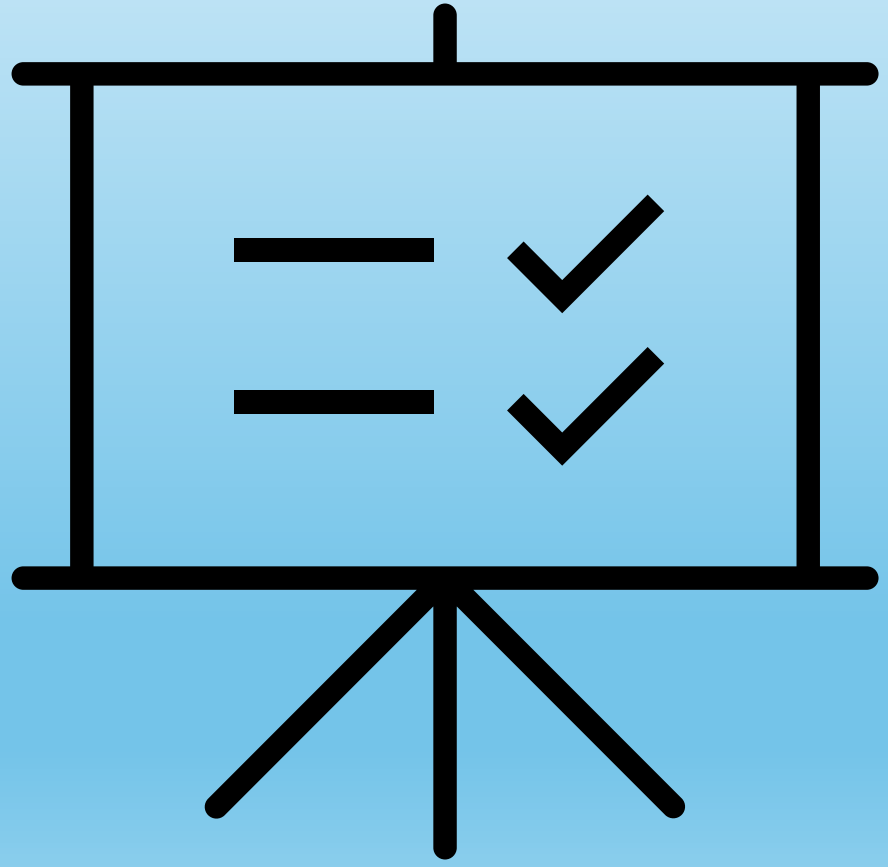
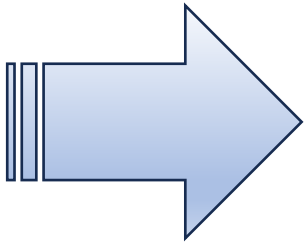


Tale of Two Studies

By

Aden O. Virus and Sam N. Ella

DEP GROUNDWATER SEPARATION STUDY



EPA WASTEWATER REUSE STUDY

This project has been financed in whole or in part with funds (competitive grants or otherwise) from the Environmental Protection Agency (EPA) and/or the Massachusetts Department of Environmental Protection (MASSDEP). The contents do not necessarily reflect the views and policies of EPA or MASSDEP, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

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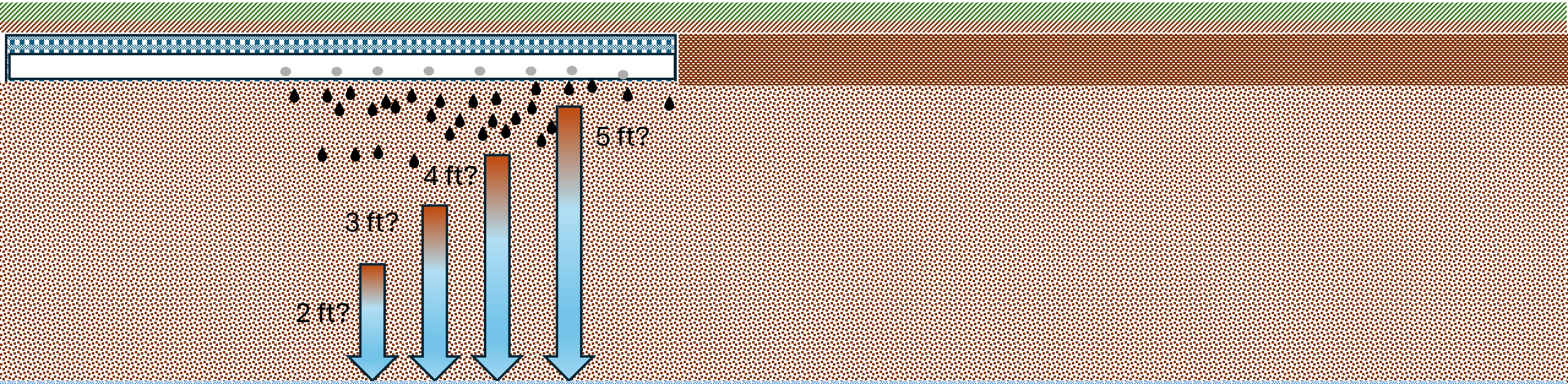
DEP Groundwater Separation Study

How much is enough ?

How much is enough ?



Massachusetts Department of Environmental Protection
Virus Entrainment Study

Study Detail

VIRUSES

- Male Specific Phages (MS-2)
- Somatic Phages
- Various animal (human) viruses

BACTERIA

- Escherichia coli
- Enterococcus sp.
- Fecal Coliform

Massachusetts Department of Environmental Protection
Virus Entrainment Study

Study Detail

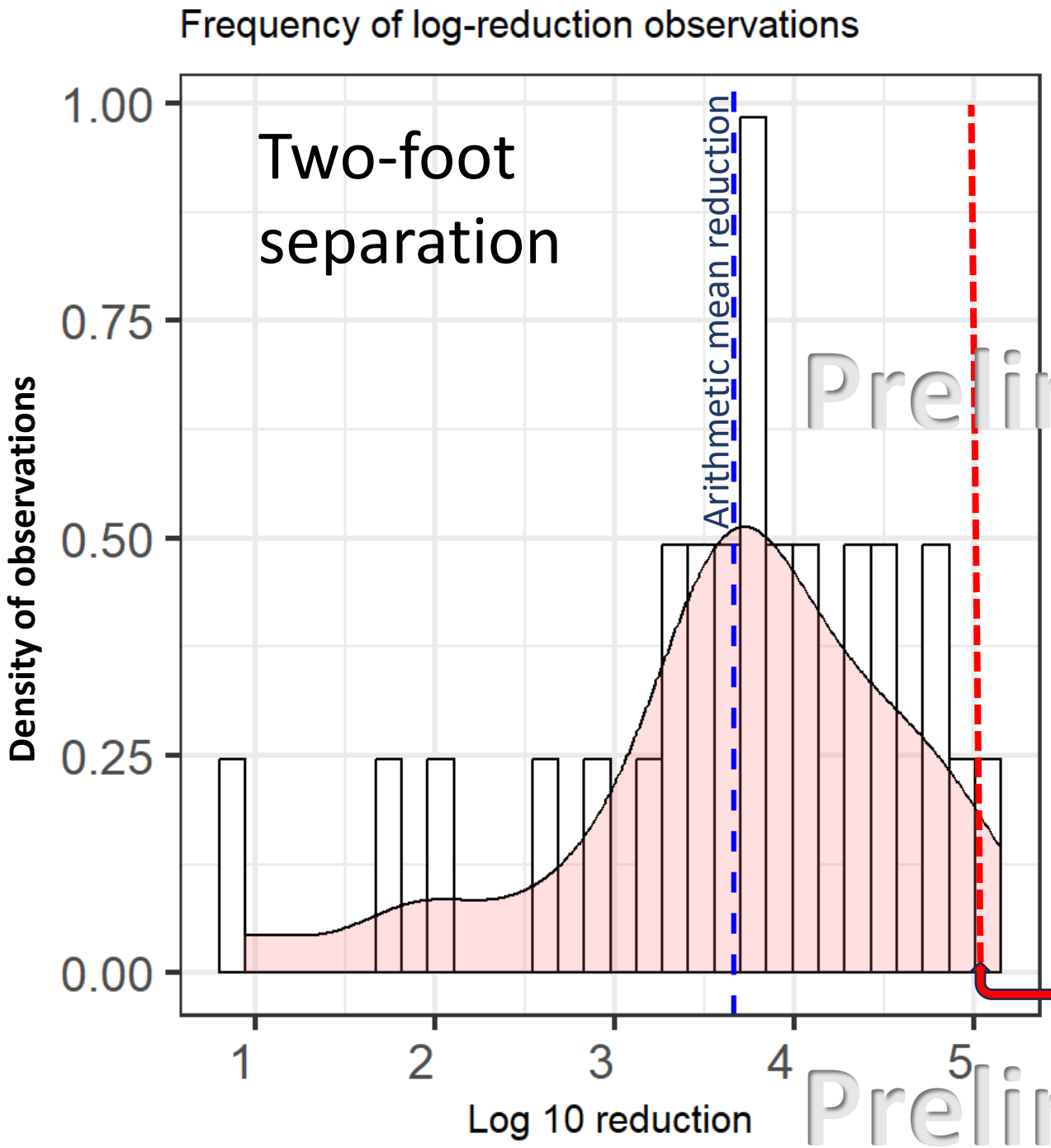
Gravity Fed

- 2-FT x 5 replicates
- 3-FT x 5 replicates
- 4-FT x 5 replicates
- 5-FT x 5 replicates

Pressure dosed

- 2-FT x 5 replicates
- 3-FT x 5 replicates
- 4-FT x 5 replicates

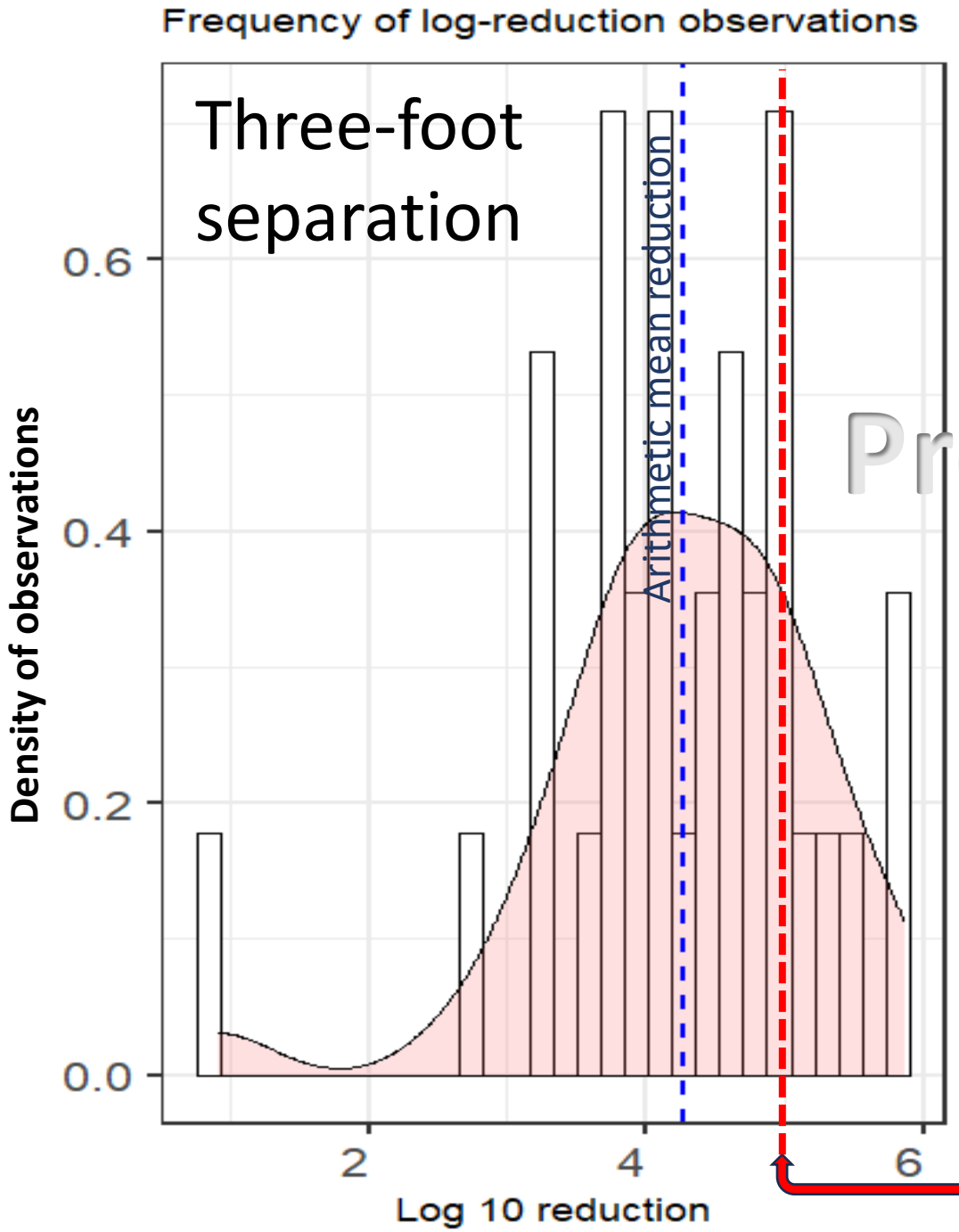
Total 35 replicates



Log removal summary for Somatic Phage at a two-foot collection point beneath standard pipe-in-stone leachfield.

Informal target Title 5 before groundwater contact

Preliminary Assessment



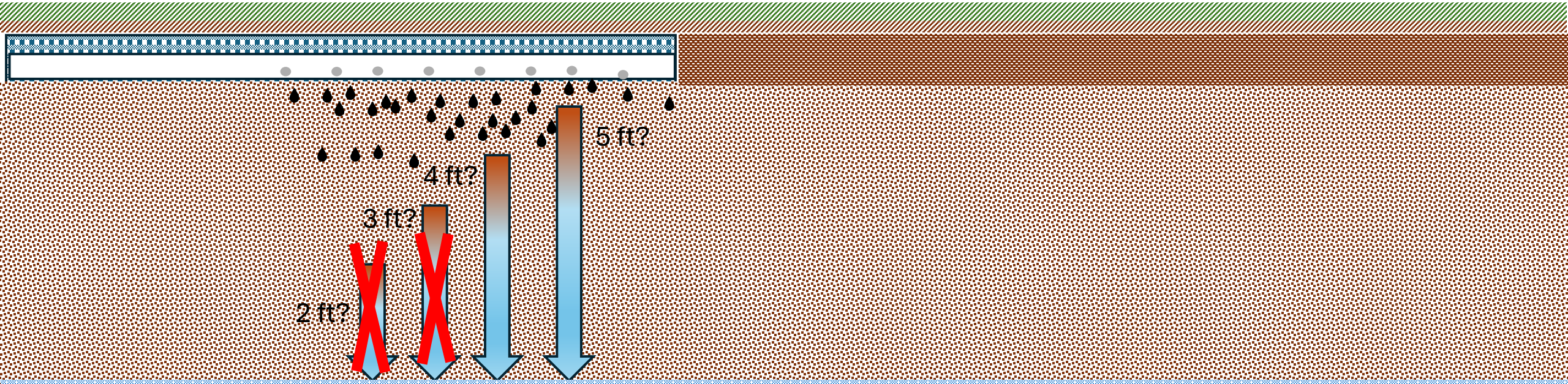
Log removal summary for Somatic Phage at a three-foot collection point beneath standard pipe-in-stone leachfield.

Informal target Title 5 before groundwater contact

DEP Groundwater Separation Study

How much is enough ?

Data initially suggest



Preliminary Assessment

Enter EPA "Water Reuse"

Human Virus And Viral Surrogates As Measures Of Water Reuse Potential From Centralized And Decentralized Wastewater Treatment

Fitness for reuse level

Drink it?
Swim in it?
Water food crops?
Landscape irrigation?
Shower in it?
Flush toilet use?

1 log = 90% reduction
2 log = 99% reduction
3 log = 99.9% reduction ← **Two-foot separation**
4 log = 99.99% reduction
5 log = 99.999 % reduction ← **Informal target Title 5 before groundwater contact**
6 log = 99.9999 % reduction ← **WHO for unrestricted irrigation**
7 log = 99.99999% reduction
8 log = 99.999999% reduction
12 log=99.9999999999% reduction ← **California for direct reuse**

Technologies investigated

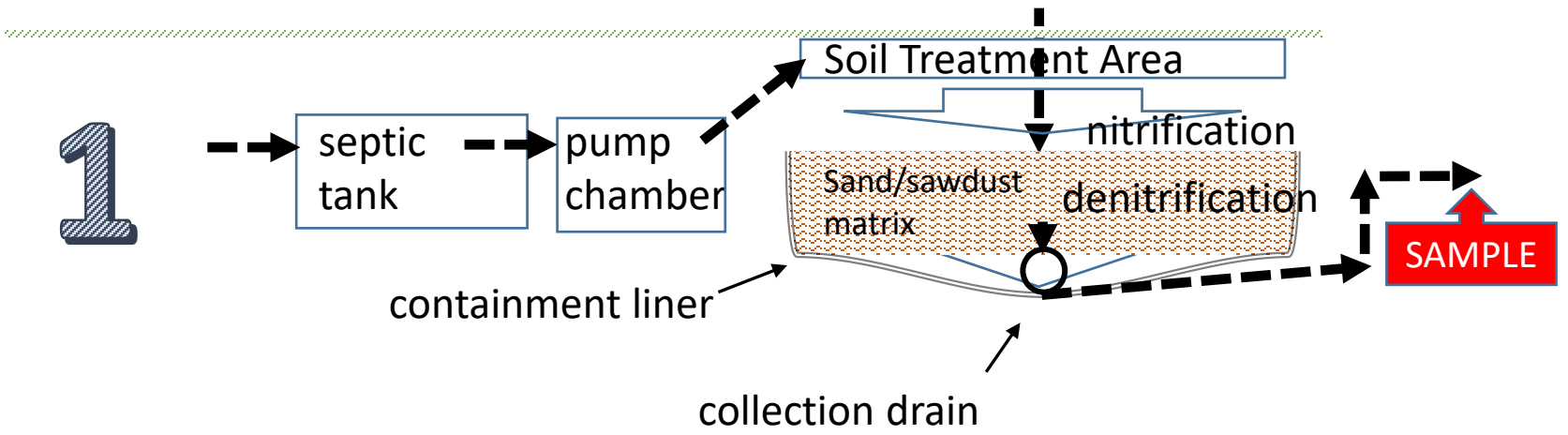
- **Cellulose-based denitrification**
- **Soils-based treatment (collecting under leachfields and reusing)**
- **Membrane Bioreactor**
- **“Toilet of the Future” – located at Cape Cod Community College**
- **Onsite biodigester**
- **Municipal treatment plants**

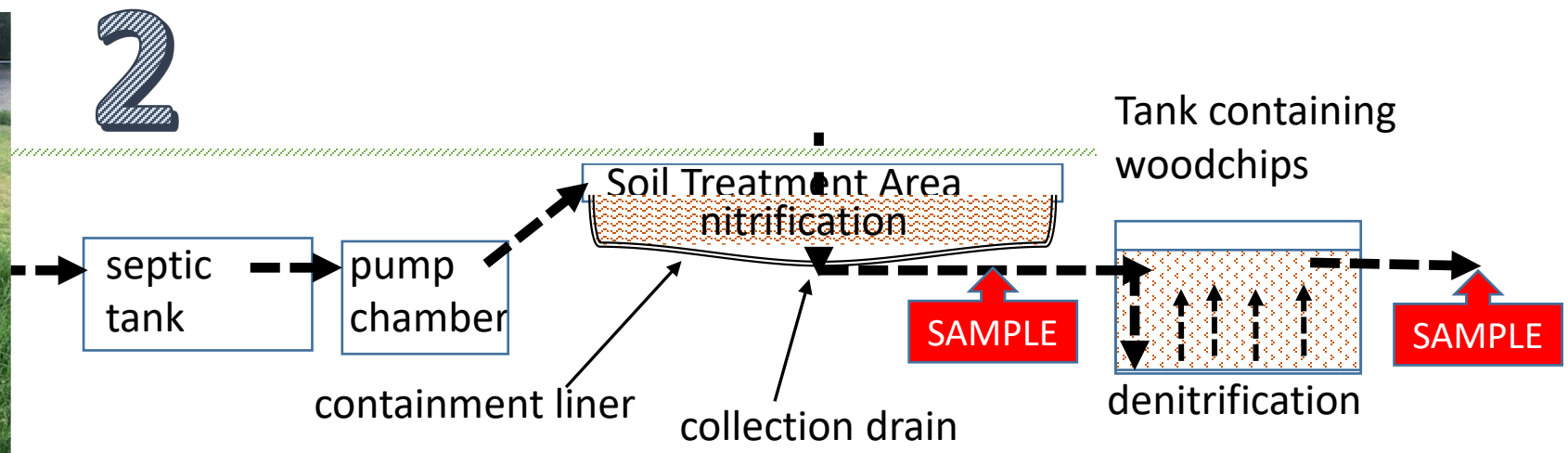
Technologies Investigated

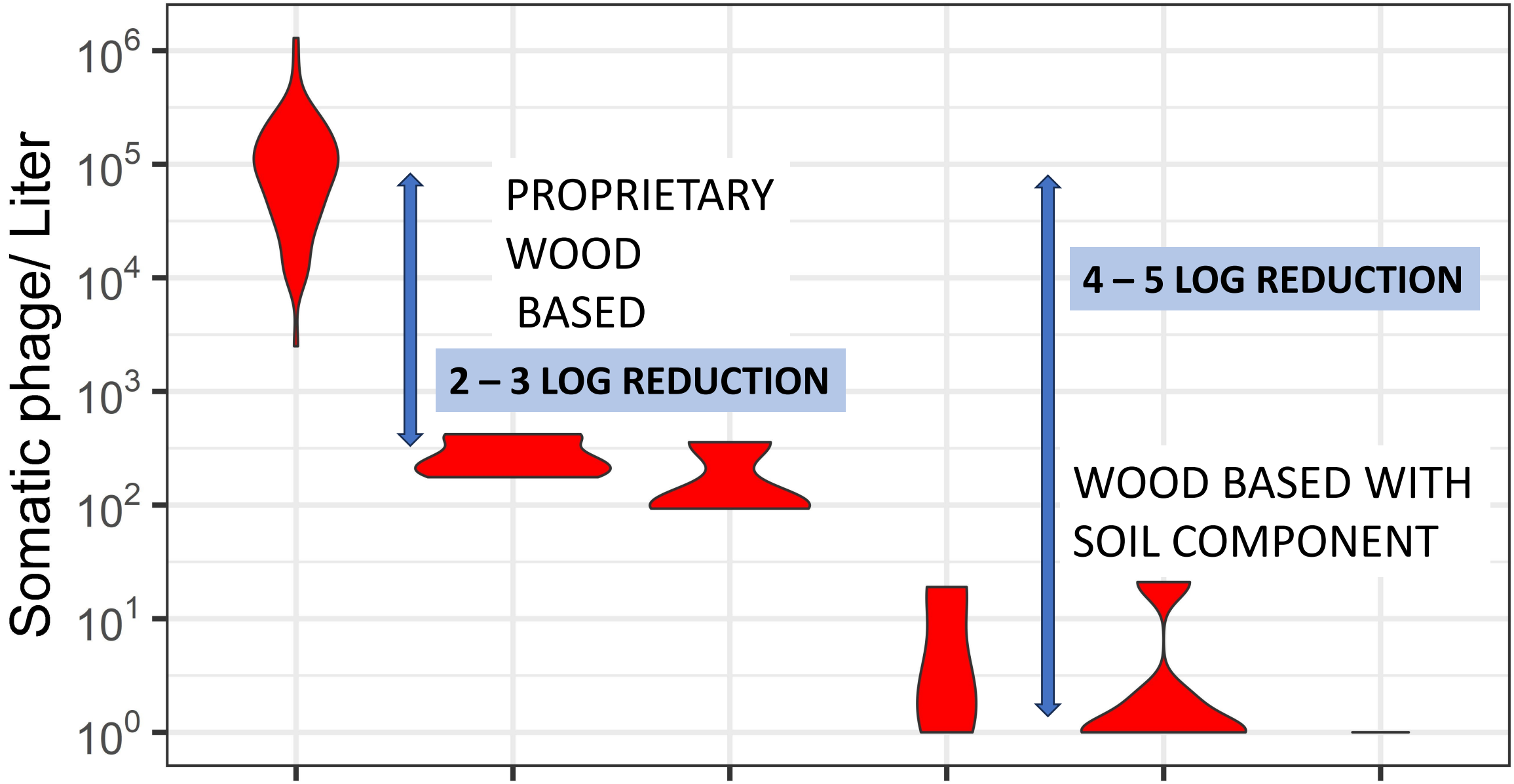
Cellulose –based systems

Systems which have cellulose by-products as a basis for the denitrification of septic tank effluent

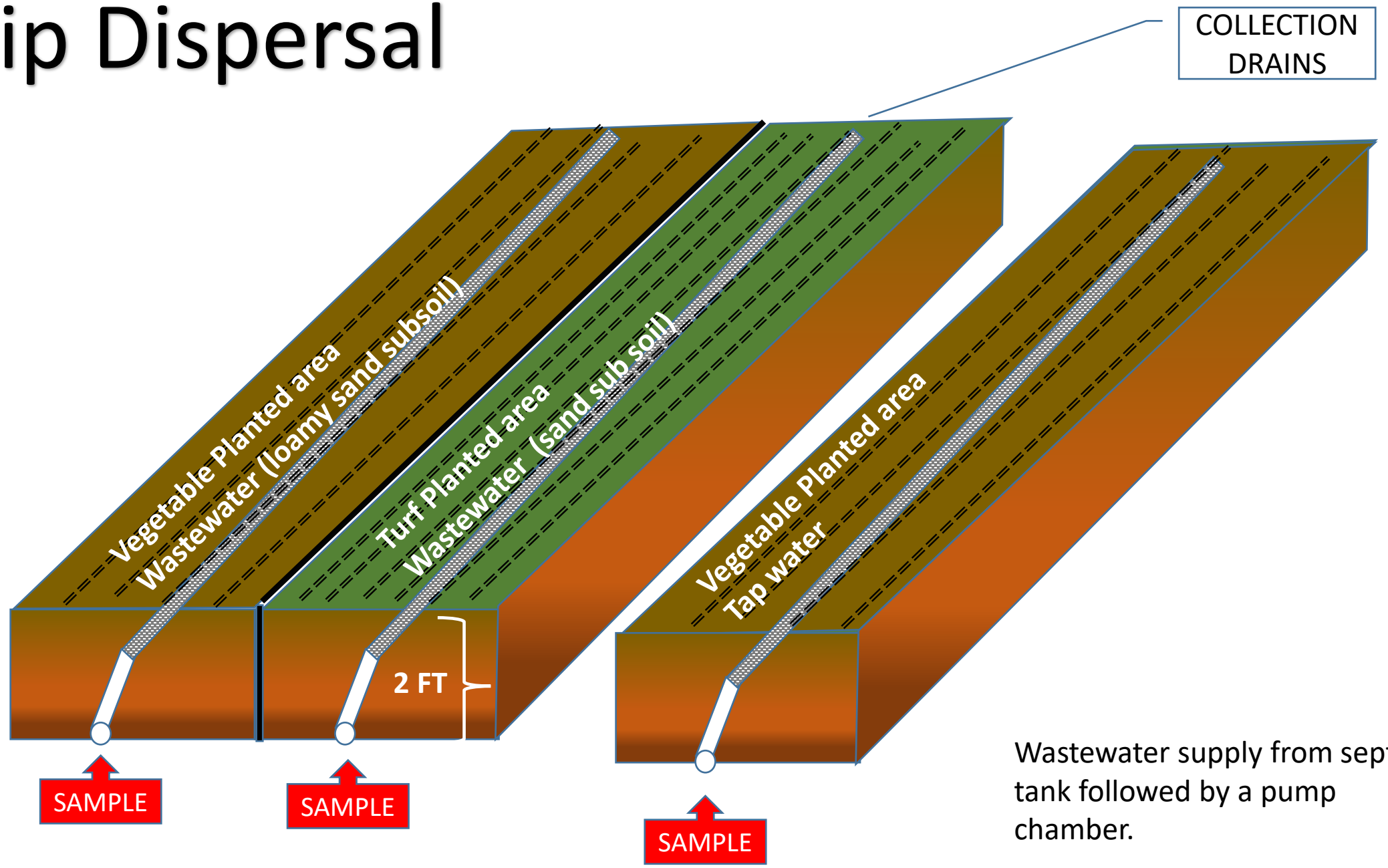
Cellulose-based denitrification systems






Somatic phage/ Liter
10^6
10^5
10^4
10^3
10^2
10^1
10^0
PROPRIETARY
WOOD
BASED
2 – 3 LOG REDUCTION
4 – 5 LOG REDUCTION
WOOD BASED WITH
SOIL COMPONENT

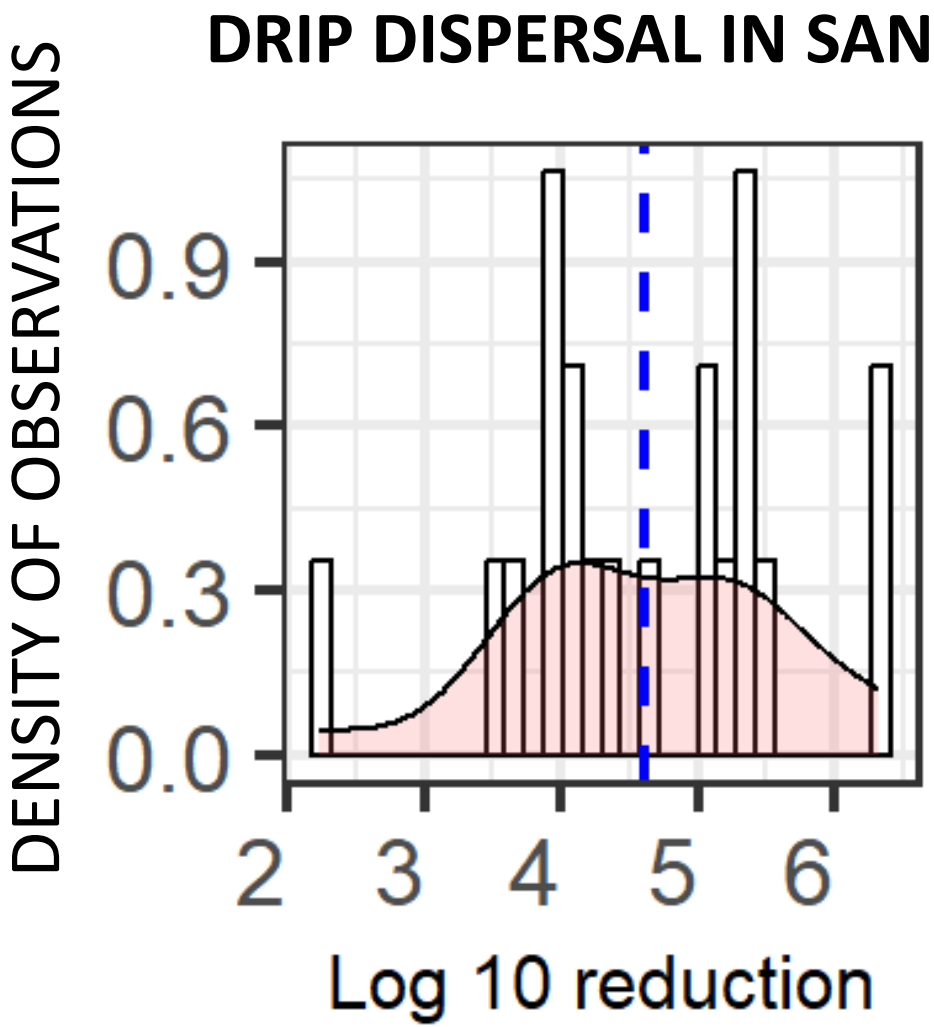
Drip Dispersal

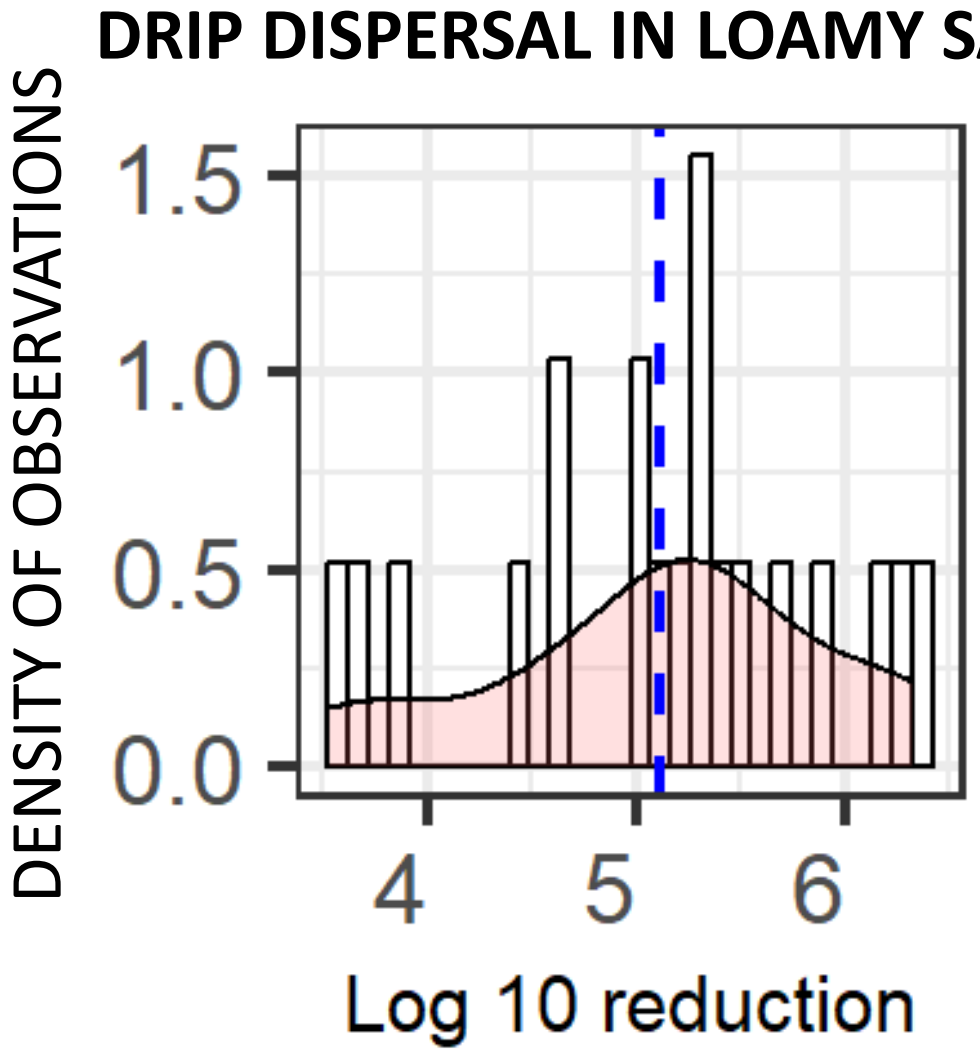


Wastewater supply from septic tank followed by a pump chamber.

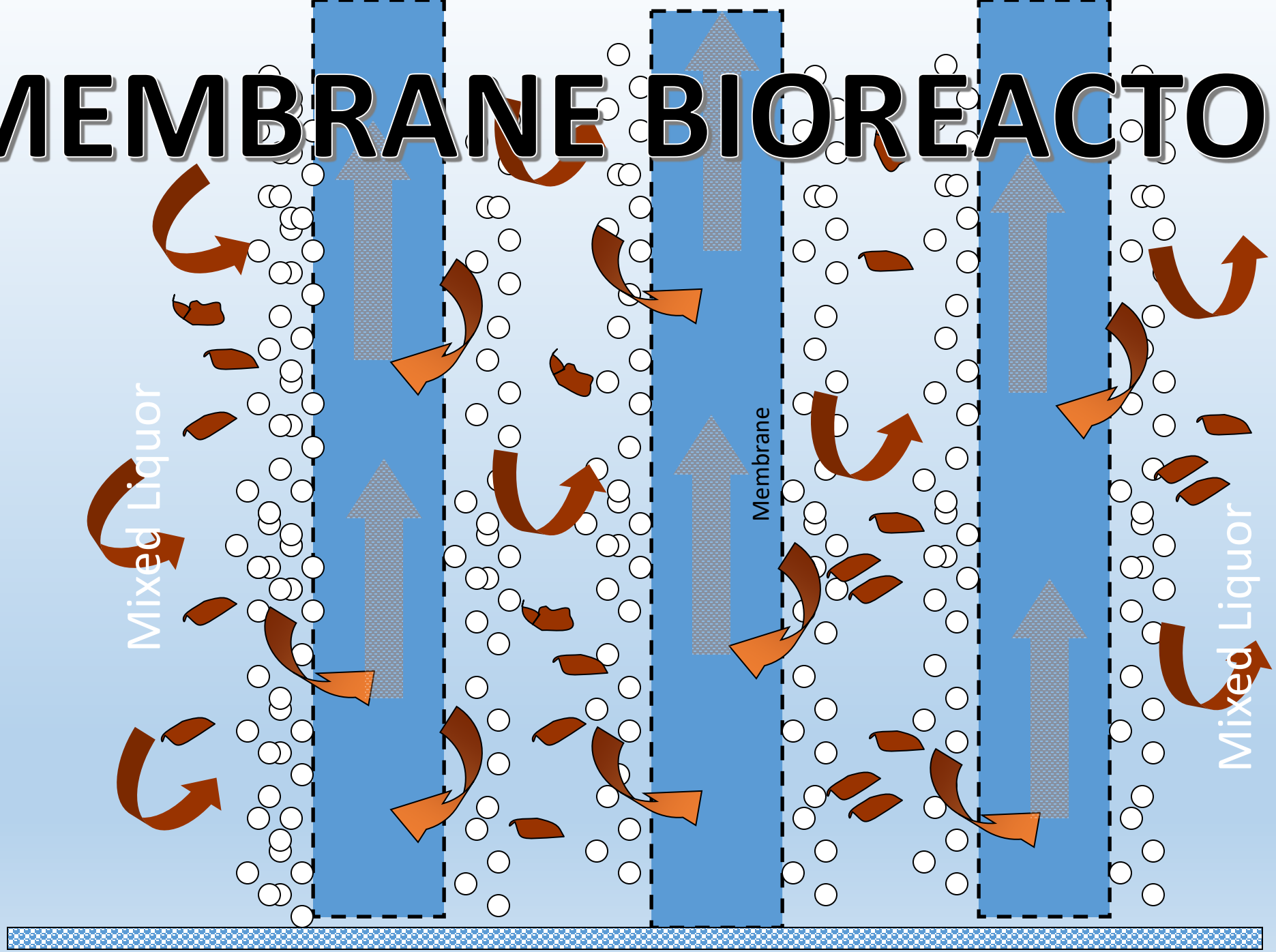
WHAT WE LEARNED

What a difference a soil makes

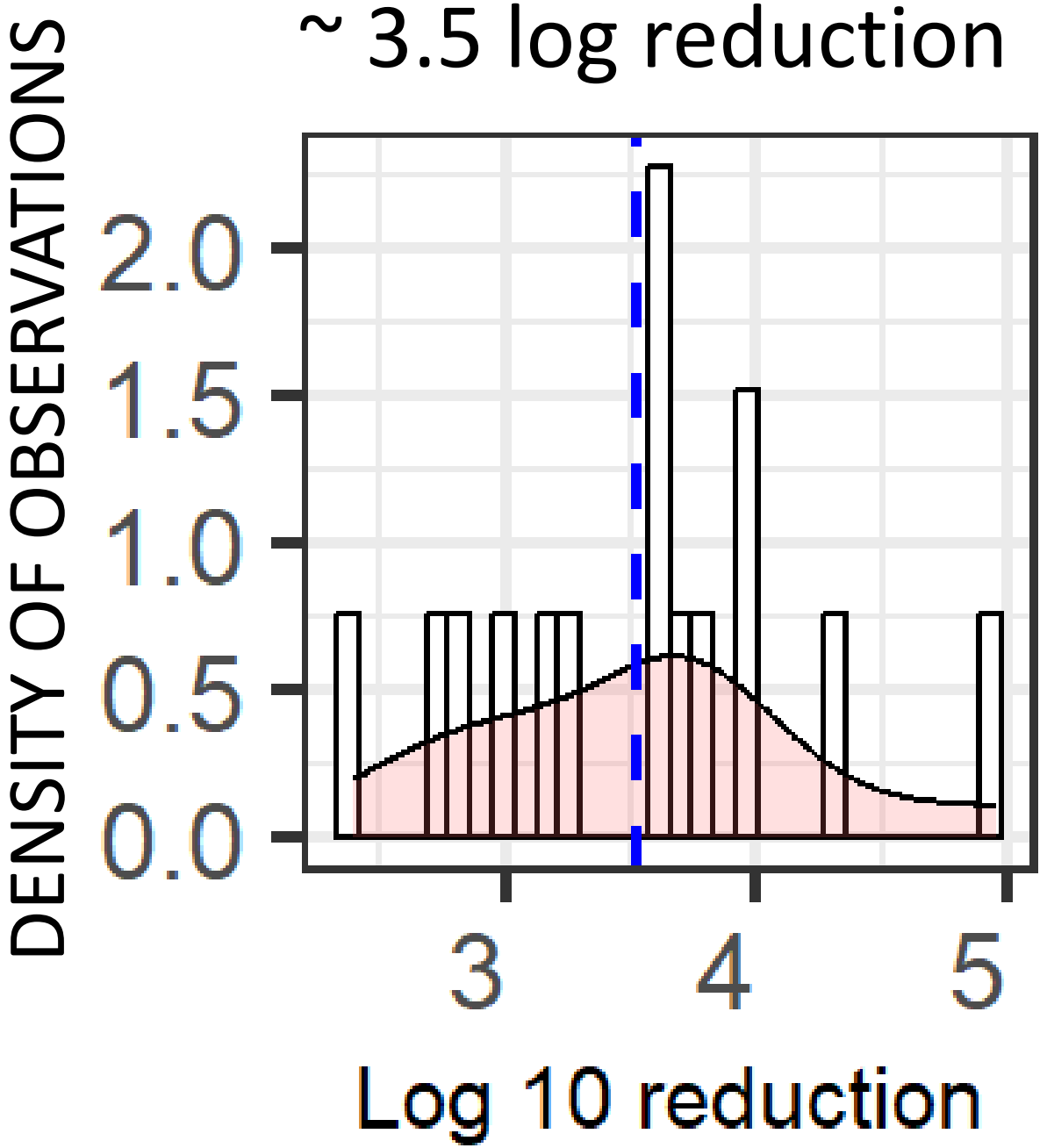




MEMBRANE BIOREACTORS

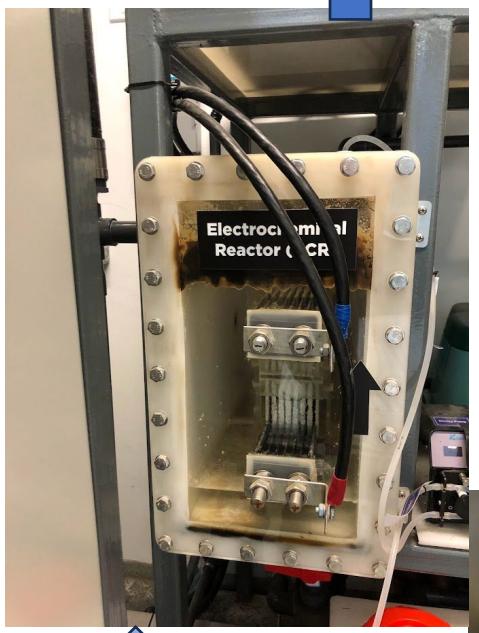



03/31/2008

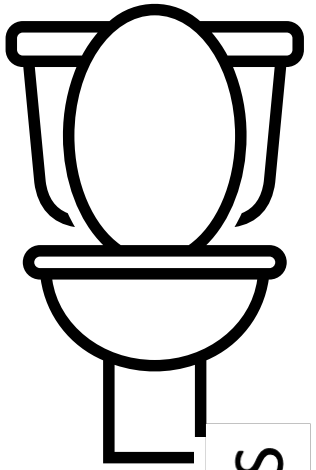

~ 3.5 log reduction
DENSITY OF OBSERVATIONS
2.0
1.5
1.0
0.5
0.0
3
4
5
Log 10 reduction

Toilet of the Future

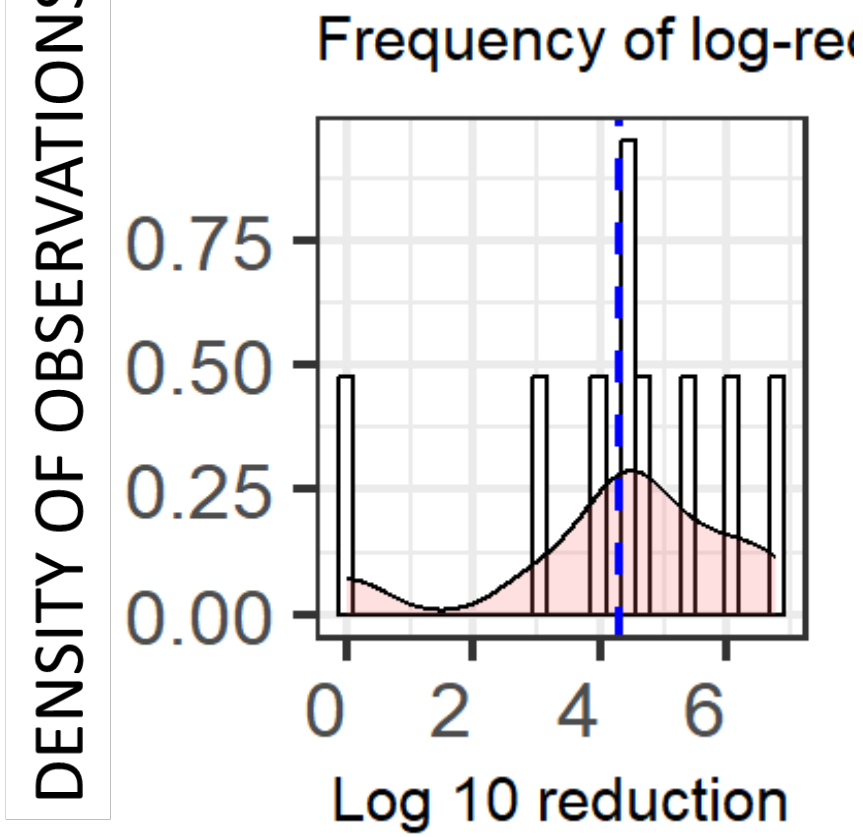
CAPE COD COMMUNITY COLLEGE
Powerful Futures Start Here



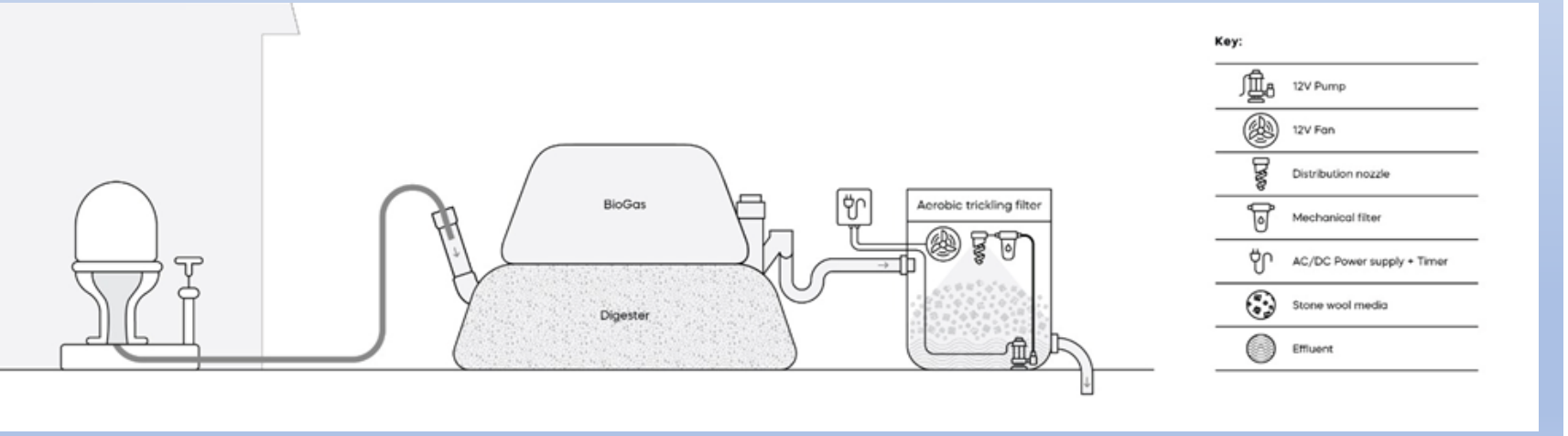
Electrochemical production of disinfectant



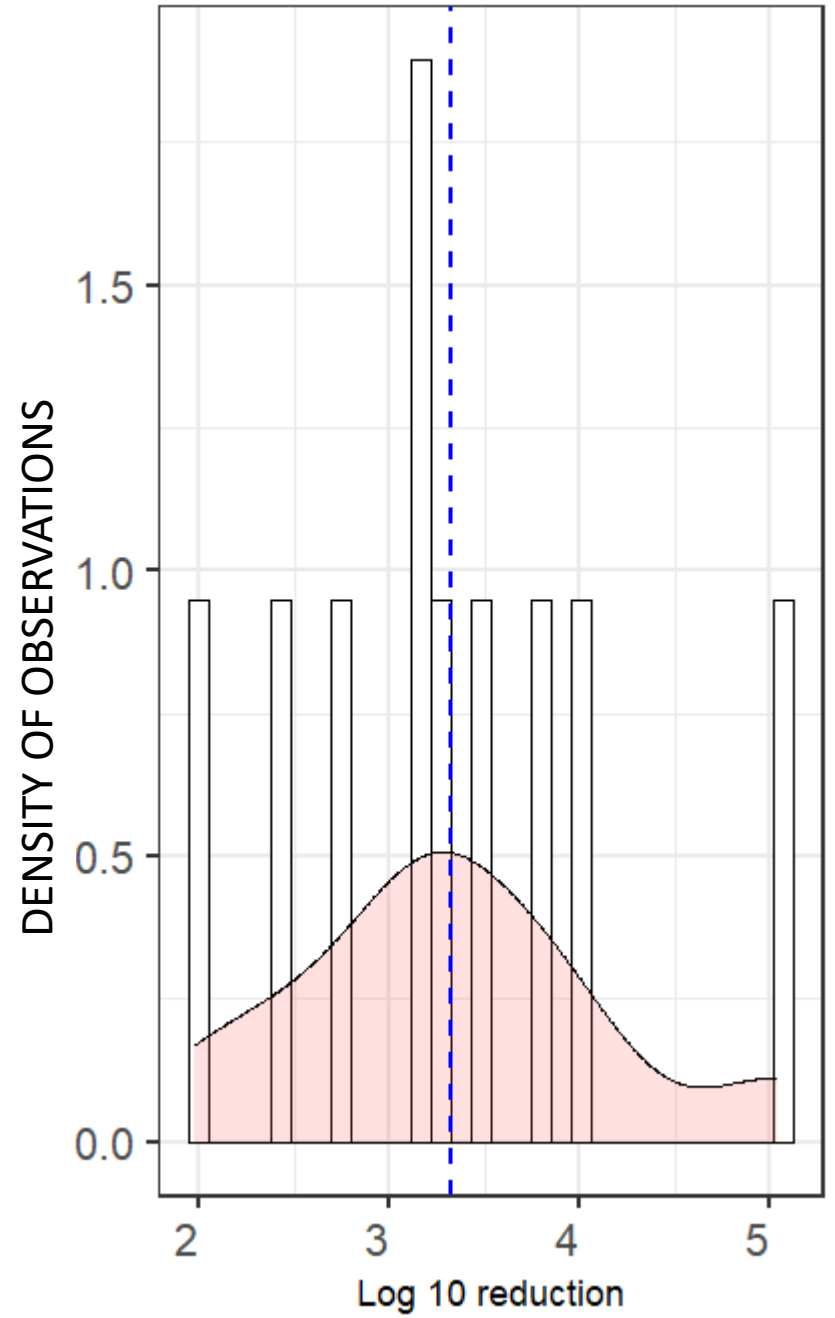
4+ log reduction



Onsite Biogas Generator – Takes human waste and organic matter and converts it to usable methane for cooking or lighting.



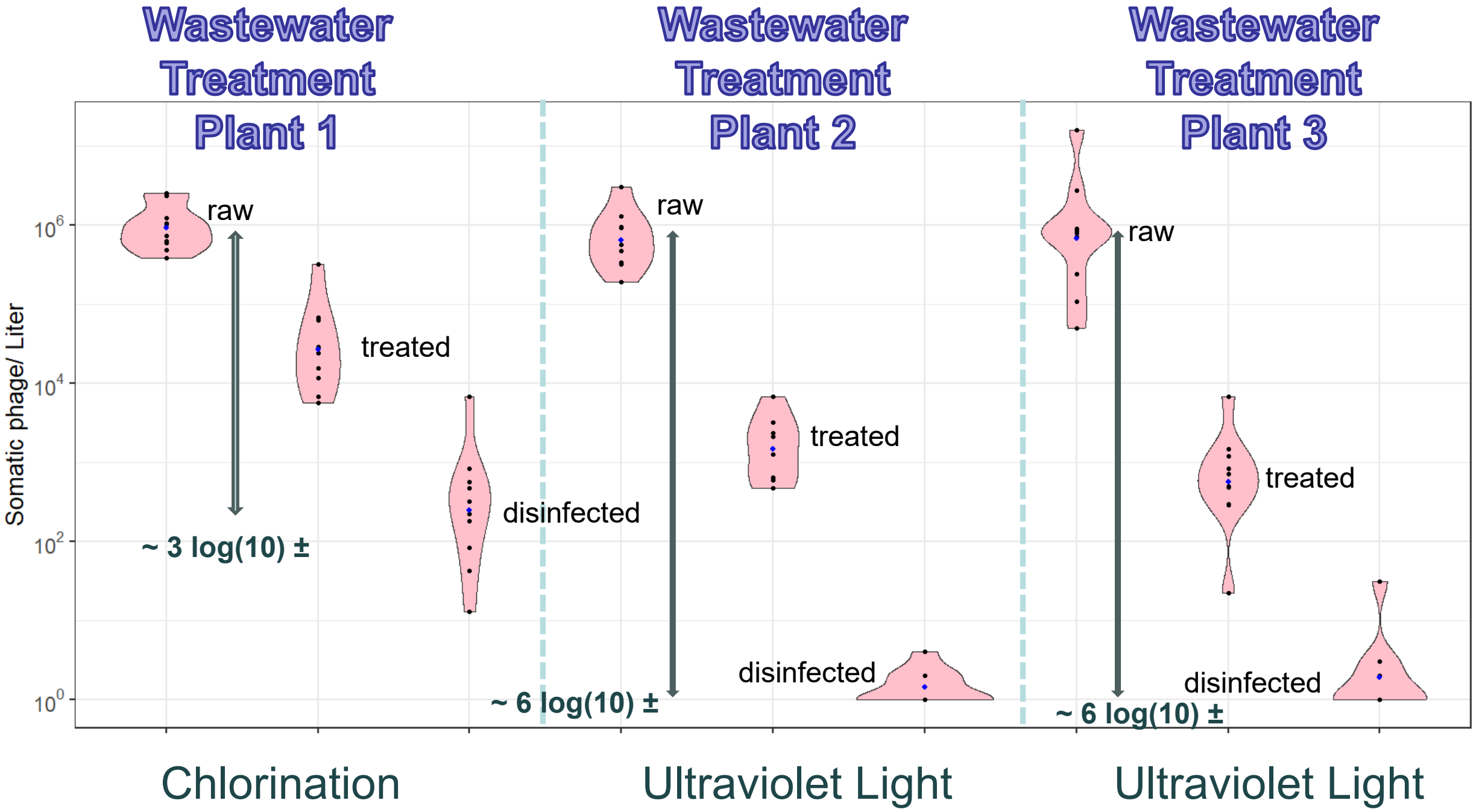
~ 3 log(10) removal ±



Three municipal treatment plants

Two treatment processes
Two disinfection processes


U-V
Control
Panel
Ultra-Violet Light Exposure Channel


Wastewater Treatment Plant 1
Wastewater Treatment Plant 2
Wastewater Treatment Plant 3
Somatic phage/ Liter
10^6
10^4
10^2
10^0
raw
treated
disinfected
~ 3 log(10) ±
raw
treated
disinfected
~ 6 log(10) ±
raw
treated
disinfected
~ 6 log(10) ±
Chlorination
Ultraviolet Light
Ultraviolet Light

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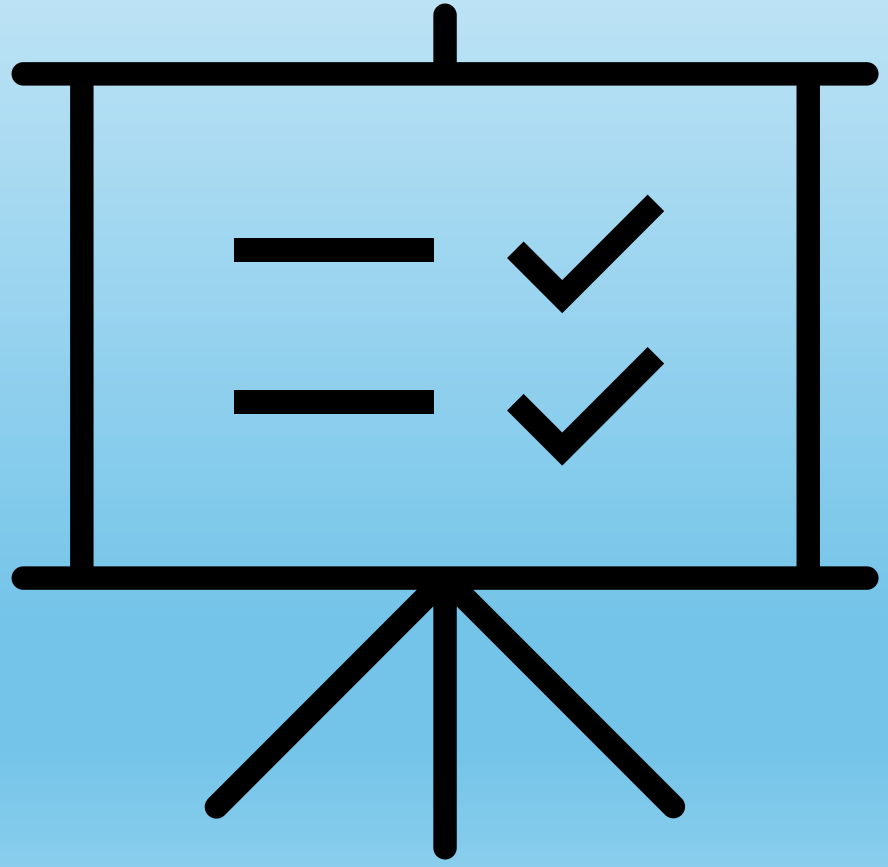


Future Directions
Nutrient recovery
Water reuse

Thank you

Questions?

MASSTC

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Septic System Test Center