TUE14 - DISTRIBUTION SYSTEM OPERATIONAL IMPACTS ON WATER QUALITY
Day: Tuesday, November 15,
Track: Distribution Systems
Time: 4:00 PM

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Challenges of Studying Water Storage Tanks in Distribution Systems: a field- and pilot-scale approach to understand the ecosystem

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WATER QUALITY Technology Conference

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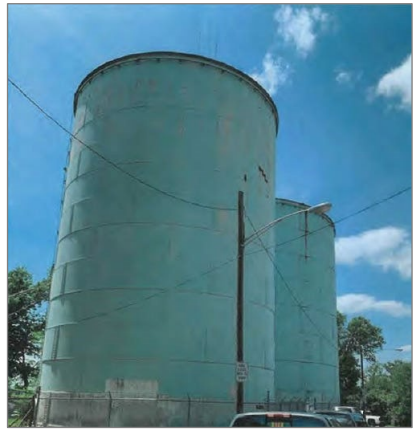
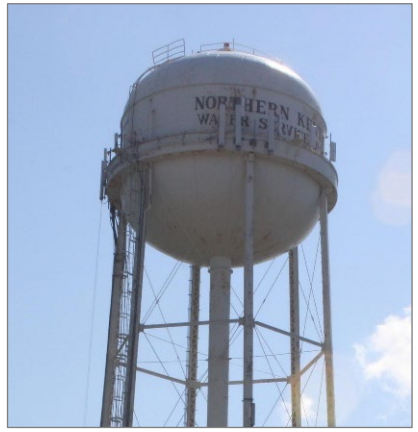
Drinking water storage tanks



Ground-level and buried tanks



Elevated tanks

Description

- storage tanks are used to **store finished water** that will undergo no further treatment to reduce microbial pathogens except **residual disinfection**.

Purpose

- designed to equalize **water demands**, reduce **pressure fluctuations**, and provide reserves for **firefighting** and other emergencies.

Why is it so important to monitor storage tanks?

Water storage tanks are **large capital assets**. The maintenance and monitoring of these critical drinking water distribution system components is often **overlooked or deferred**, resulting in water **quality violations**, **customer complaints** and **service disruptions**.

Image from: https://esemag.com

Image from: https://esemag.com

Image from: https://www.cityandstateny.com

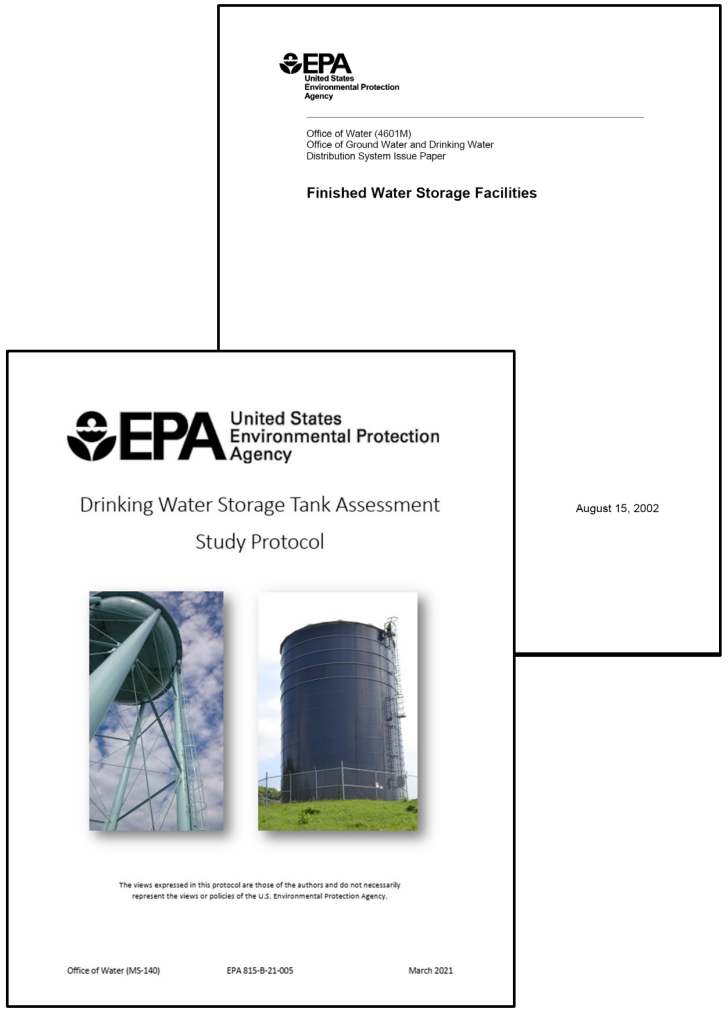
Water quality problems associated with storage tanks

Chemical	Biological	Physical
• disinfectant decay • chemical contaminants* • DBP formation* • taste and odors	• microbial regrowth* • nitrification* • pathogen contamination* • taste and odors	• corrosion • temperature/stratification • sediment*

*Water quality problem with direct **potential health impact**.

Adapted from: US EPA (2002) *Finished Water Storage Facilities*.

Federal regulations

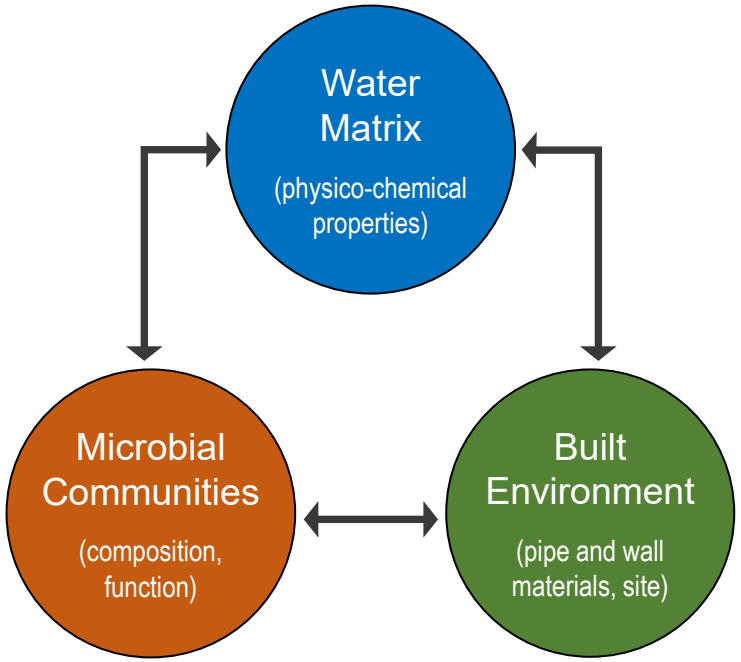


There are **no specific federal regulations** for water quality monitoring or inspection of storage facilities.

A series of white papers were published by the **US EPA** as a resource to provides a guidance on how to assess the impact of tank **operations**, **inspect** and **clean** water storage tanks.

Storage tank systems: *a complex ecosystem*

Why is it so important to examine the ecosystem?



"The formation, dynamics, and functions of [ecosystems] in storage tanks are shaped by complex interactions of factors related to the characteristics of the structure, its water physico-chemical properties, and the microbial communities associated with both."

Adapted from: NAS (2017) *Microbiomes of the Built Environment*.

A complex ecosystem

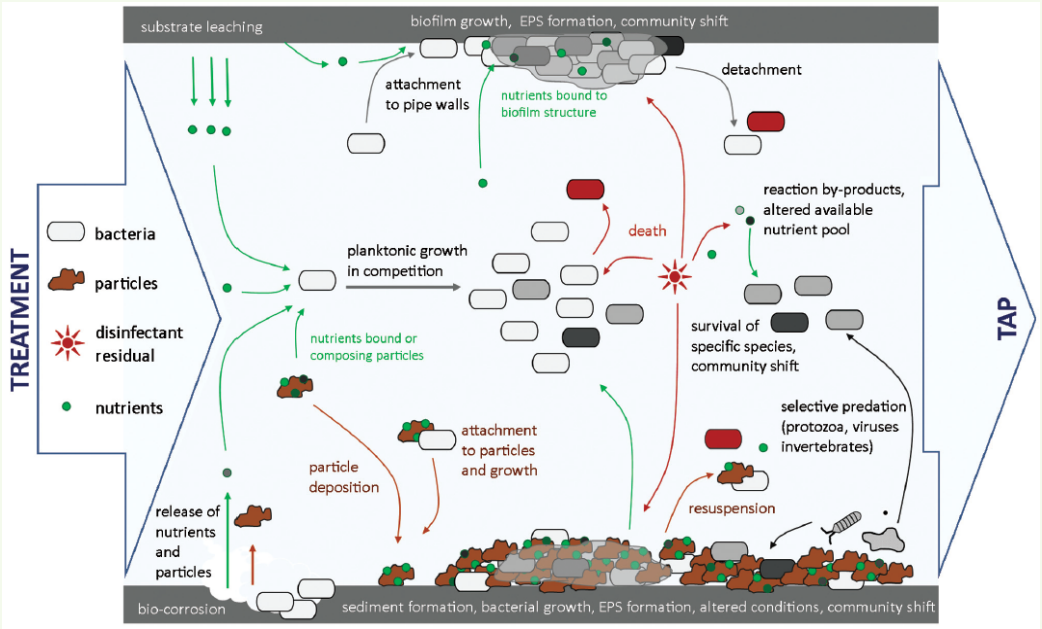


Image from: Prest *et al.*, (2016) *Front Microbiol*, 7:45.

Bridging the microbiome in storage tank systems

Microbiome involves a **microbial community** occupying a well-defined **habitat** which has distinct physio-chemical properties.

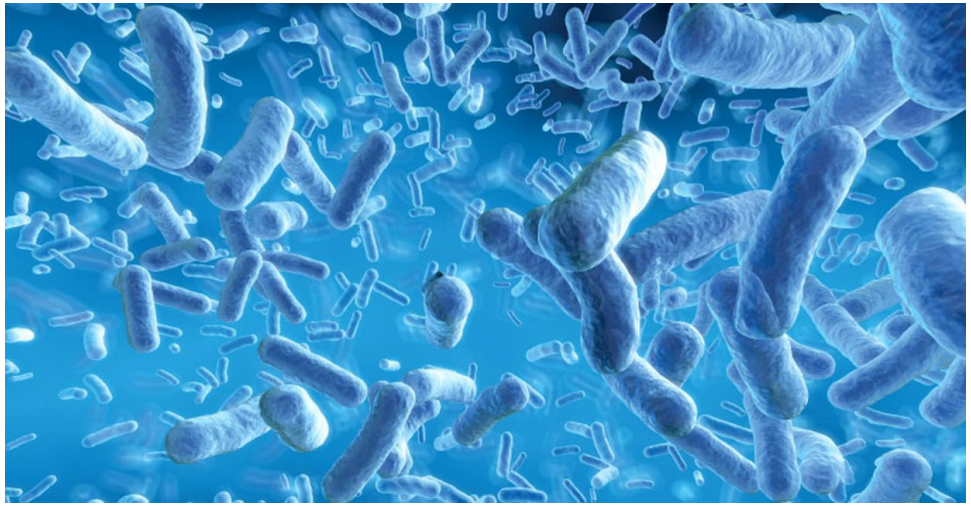


Image from: https://www.ucsf.edu

Understanding the **microbiome** is essential for monitoring the **biological stability** of the system.

This information could be incorporated into **water management programs** which identify hazardous conditions and include steps to **minimize** bacteria growth and spread in tanks.

Research methods: *decoding tank ecosystems*

Research approach to study storage tanks

Field-based study

- **Type**: observation/survey
- **Data**: point in time
- **Advantage**: conducted under natural settings
- **Disadvantage**: environmental factors are uncontrollable

Pilot-scale study

- **Type**: experimental
- **Data**: time series
- **Advantage**: conducted under controlled conditions
- **Disadvantage**: not always representative of natural environments

Research approach to study storage tanks: microbial ecology

*"**Microbial ecology** is currently undergoing a revolution [in part to the development of **N**ext **G**eneration **S**equencing* (NGS) *technology]… …the rapid accumulation of metagenomic data is uncovering vast diversity, abundant uncultivated microbial groups and novel microbial functions."*

Ingerson-Mahar and Reid (2012) *American Academy of Microbiology*, pp13.

Metagenomics involves the sequencing and application of bioinformatics to study the genetic material recovered directly from environmental samples.

Microbial Ecology is the study of microbes (communities) in the environment and their interactions.

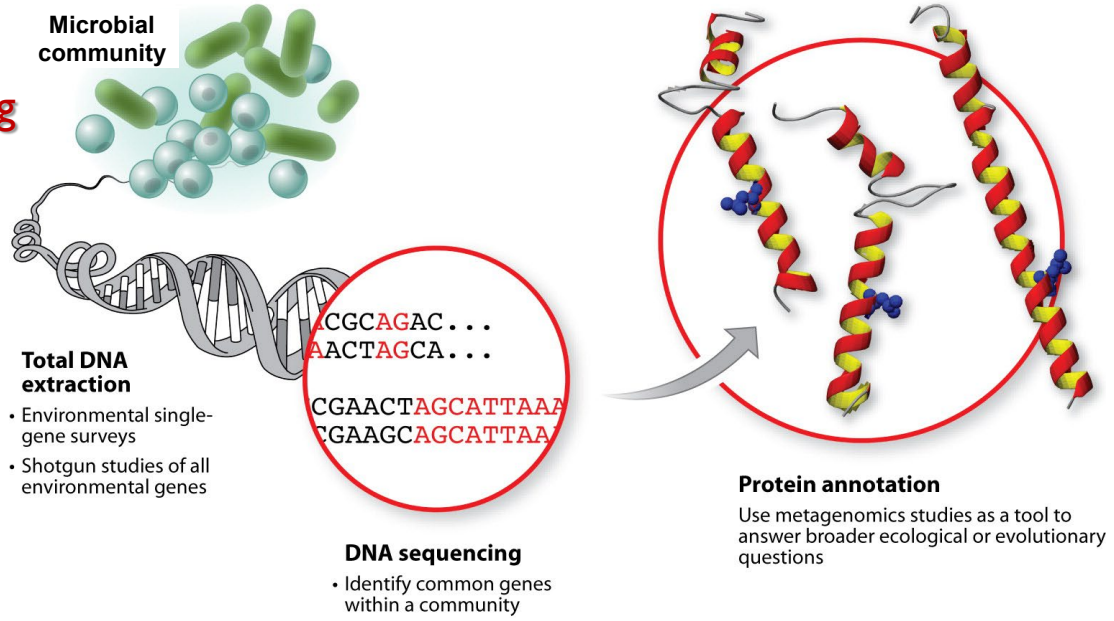
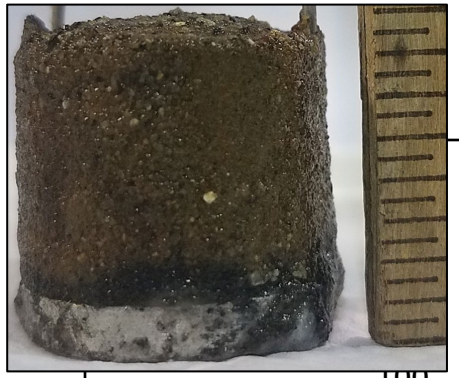


Image adapted from: Gilbert *et al*., (2011) *Ann Rev Mar Sci*, 3:347.

Research method: *field-based study*

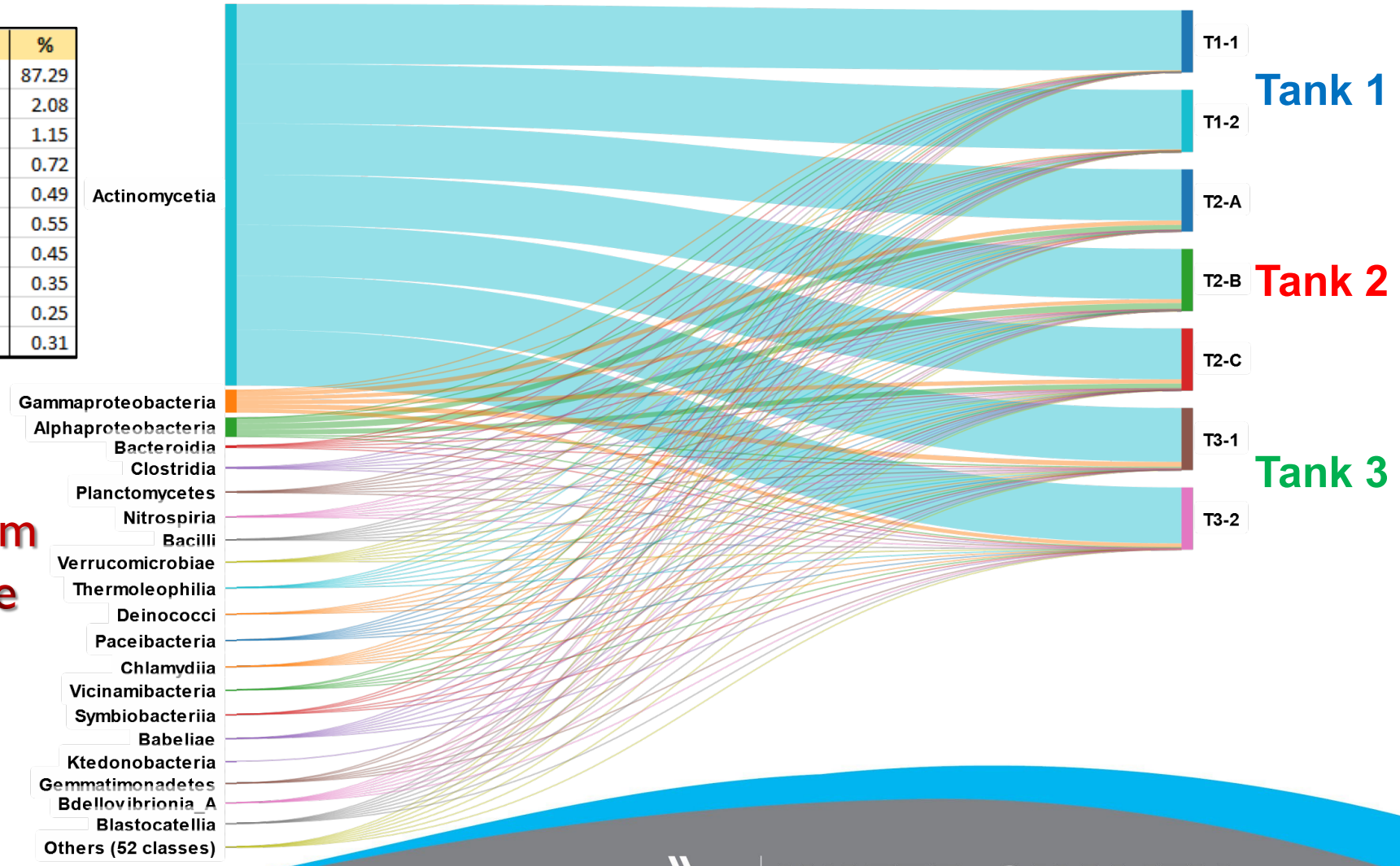
Field-based study: community profile in sediments



Tank ID	Tank Type (capacity)	Sample ID
Tank #1	Elevated, Multileg (1.0 MG)	T1-1
		T1-2
Tank #2	Ground Supported, Standpipe (0.60 MG)	T2-A
		T2-B
		T2-C
Tank #3	Elevated, Multileg (0.50 MG)	T3-1
		T3-2

Field-based study: taxonomic profile in sediments

Taxa	Size	%
Mycobacterium spp.	256,627	87.29
Nitrosomonas spp.	6,116	2.08
Rhizobiales spp. UBA4765	3,378	1.15
Rugosibacter aromaticivorans	2,121	0.72
Burkholderiaceae spp.	1,430	0.49
Novosphingobium spp.	1,616	0.55
Blastomonas delafieldii	1,325	0.45
Sphingomonas spp.	1,032	0.35
Beijerinckiaceae spp.	746	0.25
Sphingomonas spp.	899	0.31

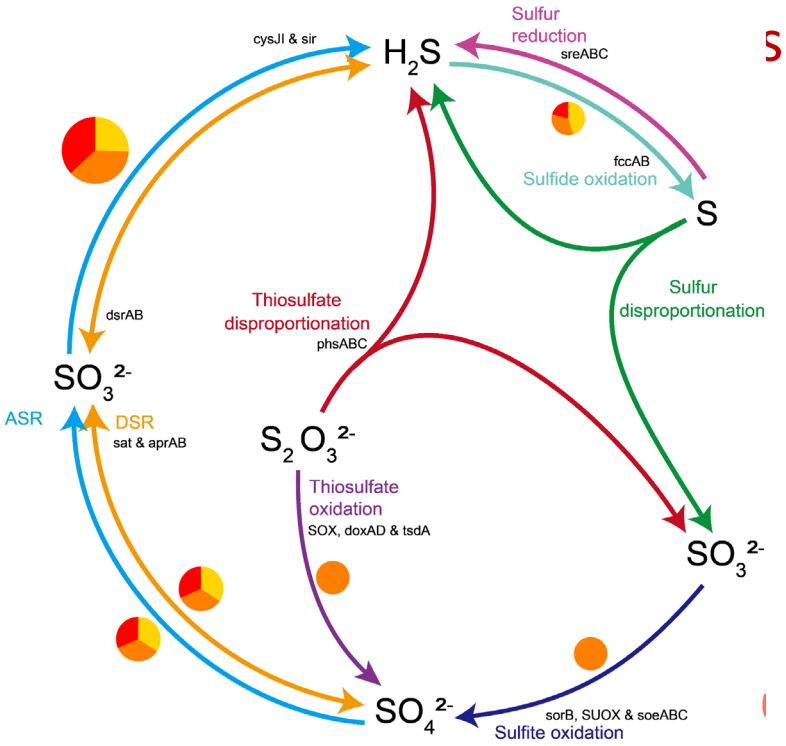


Complex ecosystem with highly diverse bacterial communities.

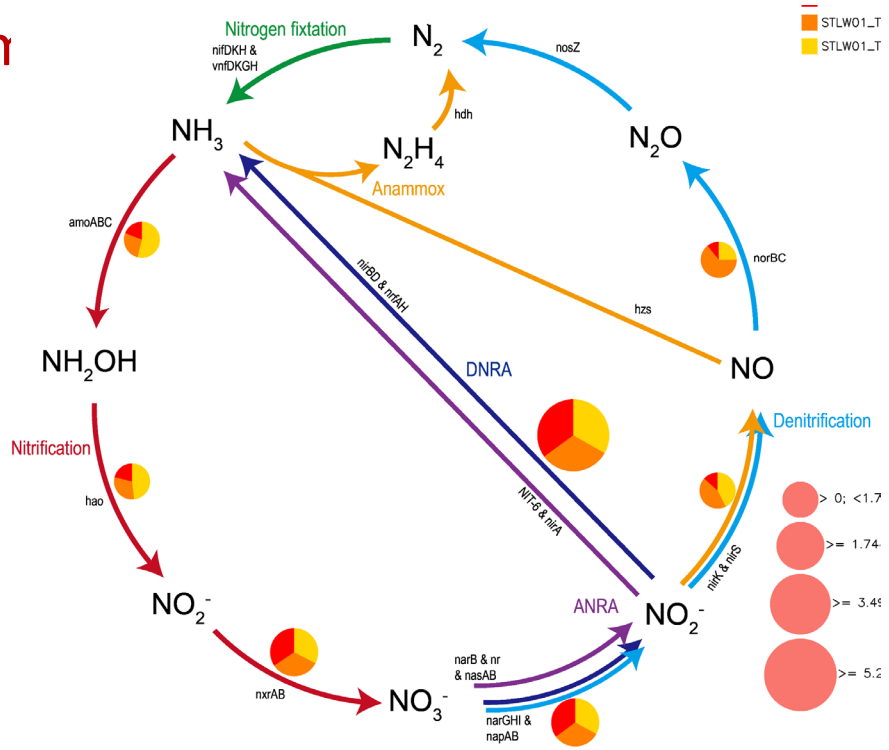
Field-based study: metabolic profile in sediments

Complexity of biogeochemical processes of the water microbiom is evident in storage tanks.

Sulfur cycle



Nitrogen cycle



Research method: *pilot-scale study*

Pilot-scale study: distribution system and water tank simulator

Chloraminated water tank (2x 2,500 gallons)

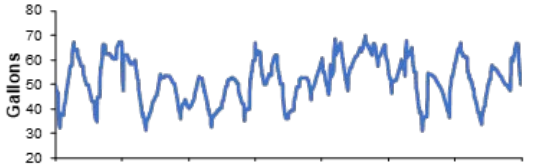
Distribution water tank (300 gallons)

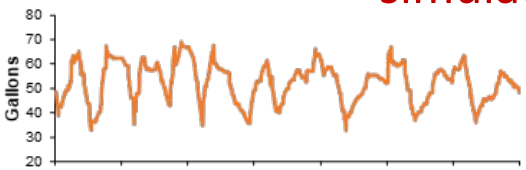
Finished water (DWTP)

Semi-closed pipe loop (23m x 24cm)

Distribution system simulator (DWDS)

Controller

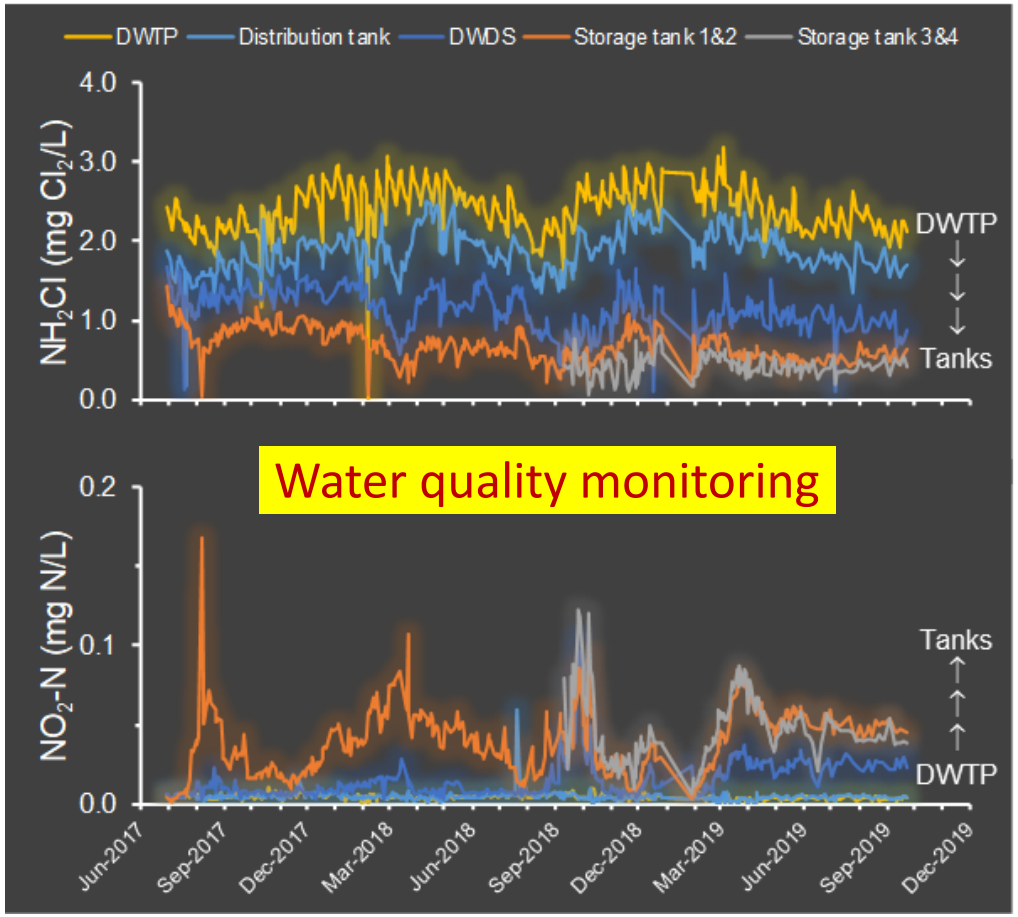


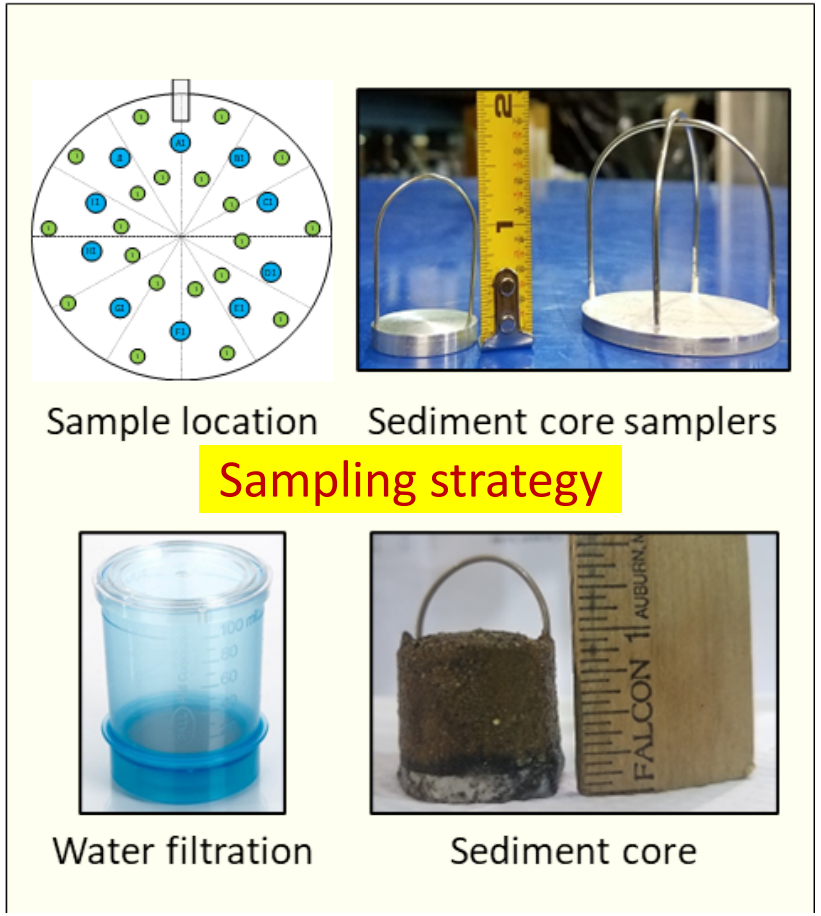


Storage tank simulator

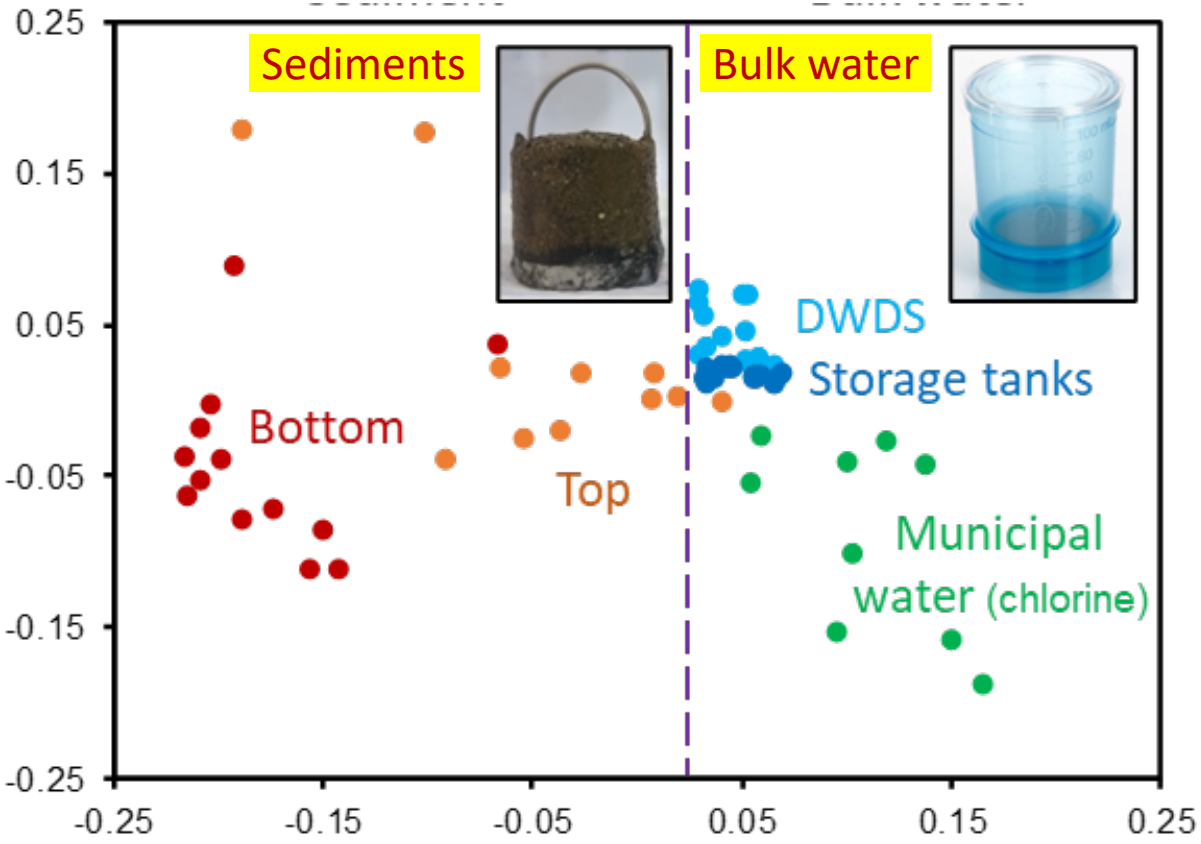
[4x] Tank (100 gallons)

Pilot-scale study: monitoring and sampling strategies [time series]

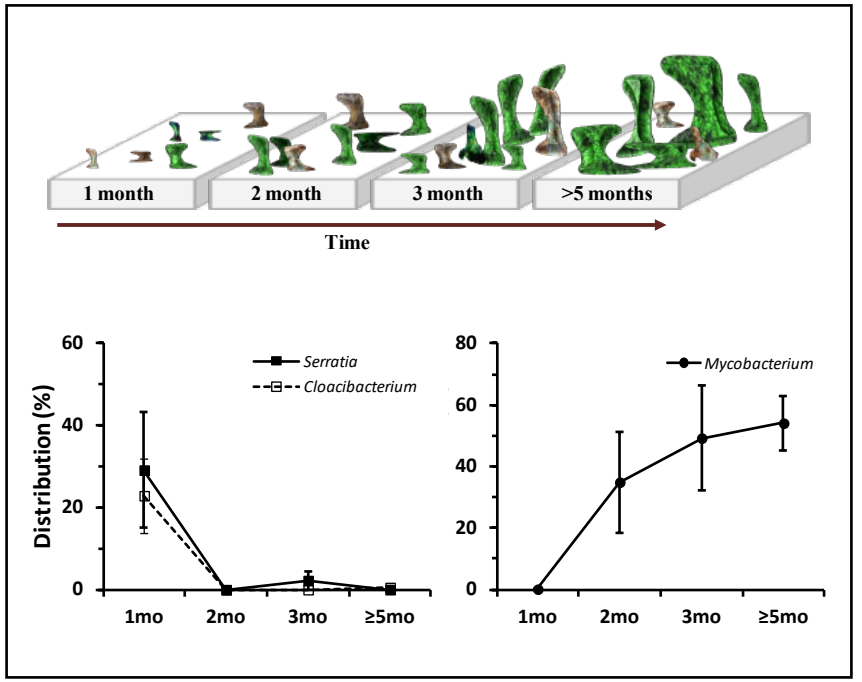




Pilot-scale study: microbial community analysis [time series]

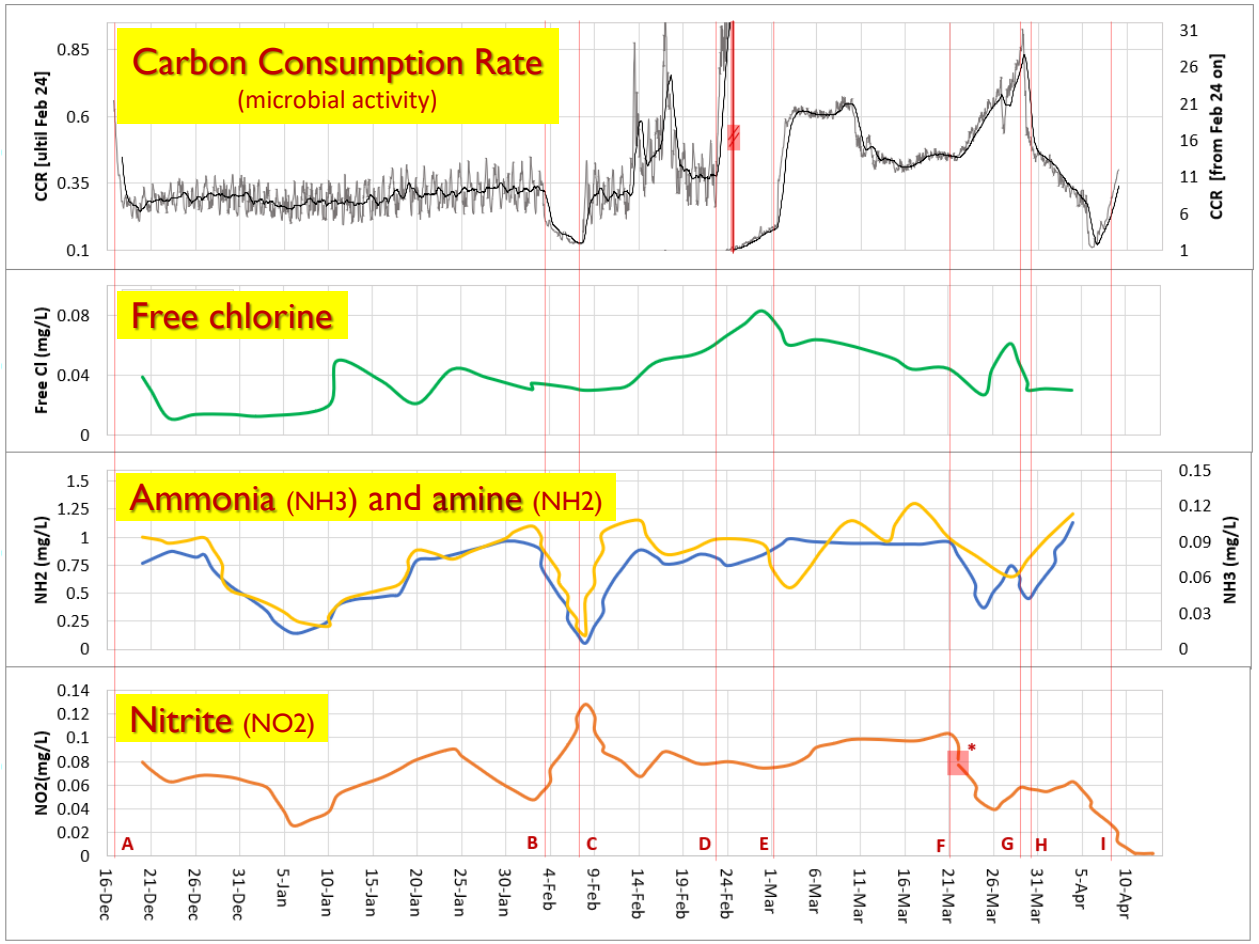


Complex ecosystem with communities structured as a function of the environment.



Biofilm development over time.

Pilot-scale study: test bed platform [ecological disturbance]



Overlay of parameters values and concentrations in storage tank simulators. **Red lines correspond to disturbance events.**

The SENTRY system was deployed in tanks to monitor daily microbial activity.

FINAL REMARKS

Practical Impact

- Demonstrated the advantages of using **field-based** and **pilot-scale drinking water simulators** to test and understand the ecosystem dynamics of the storage tanks.
- **Molecular** approaches allow the genomic analysis of unculturable microbes and role of relevant functions in storage tank ecosystems.
- **Water Storage Tanks** are complex ecosystems with highly diverse bacterial communities structured as a function of both environment [bulk water vs sediment] and sediment depth [top and bottom].

- **Ecological insight** of the microbial community could be incorporated into water management programs and guidelines to greatly enhance our ability to minimize bacteria growth and spread in drinking water storage tanks.

THANK YOU

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