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Developing Fluorescence Sensor Systems for Early Detection of Nitrification in Chloraminated Drinking Water Distribution Systems

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Agenda

- Nitrification in drinking water distribution systems
- Project drivers
- Project goals and approach
- Results to date
- Conclusions and path forward

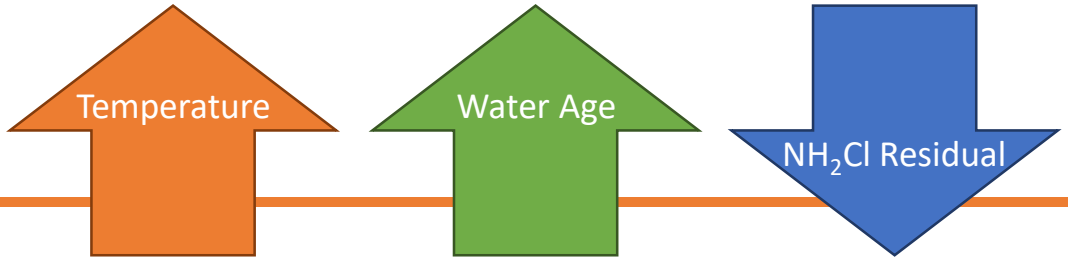
Nitrification is a biological process fueled by free ammonia

Step 1:

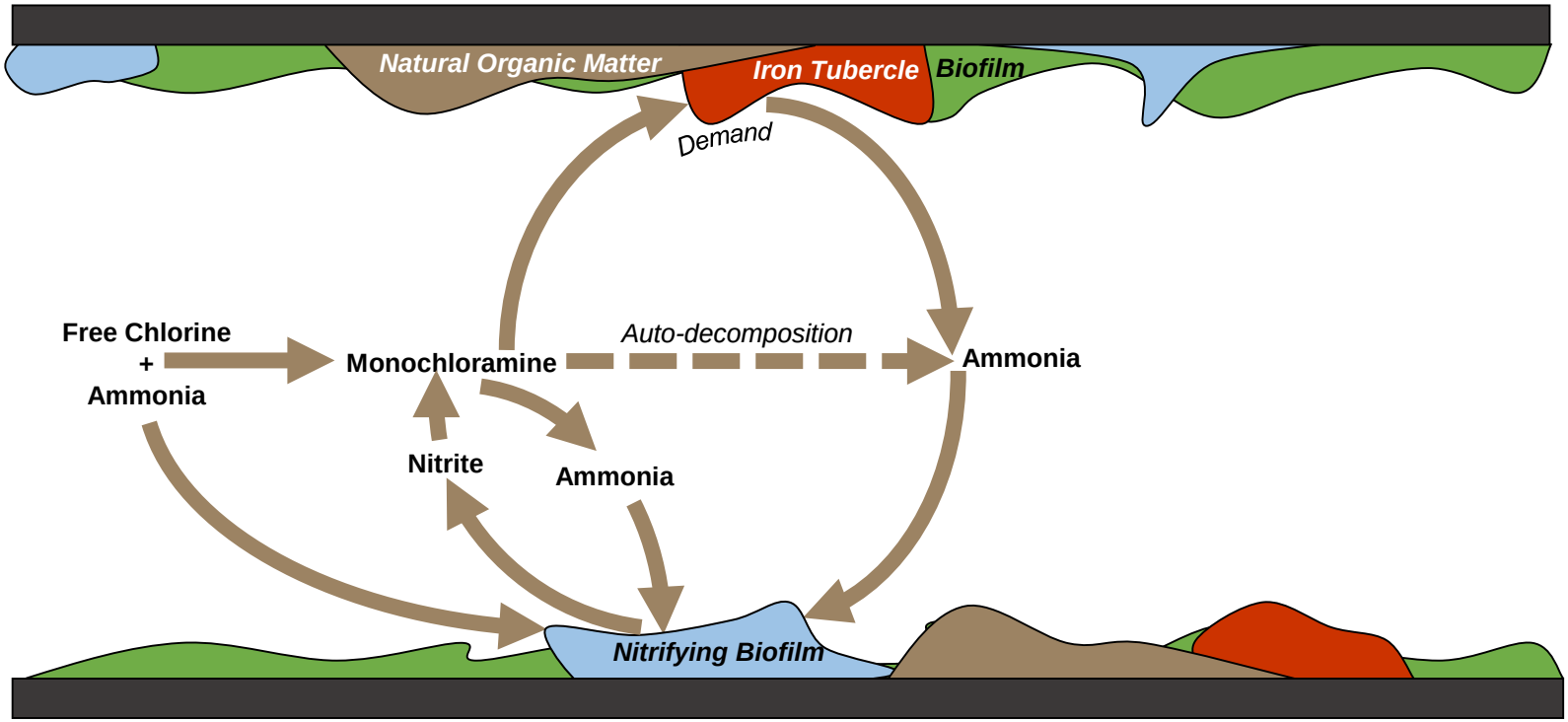
NH_3 (Ammonia) —Ammonia Oxidizing Bacteria (AOB)→ NO_2^- (Nitrite)

Step 2:

NO_2^- (Nitrite) —Nitrite Oxidizing Bacteria (NOB)→ NO_3^- (Nitrate)



Free ammonia enters the system from source water or during formation of monochloramine, and monochloramine decomposition releases ammonia



System-wide measures are needed to control nitrification

Minimize Water Age, Maximize NH_2Cl Stability and Residual, and Monitor for Nitrification

At the WTP

- Remove disinfectant demand
- Optimize monochloramine dosing

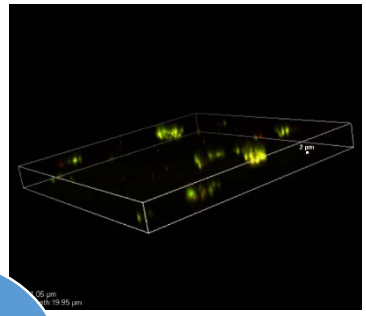
In Storage Tanks

- Minimize dead zones and thermal stratification through mixing and cycling

In Pipes

- Minimize water age through looping and flushing
- Boost the monochloramine residual

Common monitoring tools include:



Lab-Based Tools

Microbiological characterizations, Ion chromatography, UV spectroscopy

Portable Analyzers

Colorimetric

Online Analyzers

Colorimetric or Amperometric

Critical parameters include: total chlorine, monochloramine, free ammonia, nitrite, nitrate, pH, and temperature

Image from: www.hach.com

Nitrification monitoring and control has been a challenge for large systems in warm regions

Dallas Water Utilities

Directly serves 1.2 million

3 Surface Water Treatment Plants (100% of supply)

5 billion gallons of water (~$43M) lost annually to water quality-related flushing

Past nitrification events went hand-in-hand with red water complaints

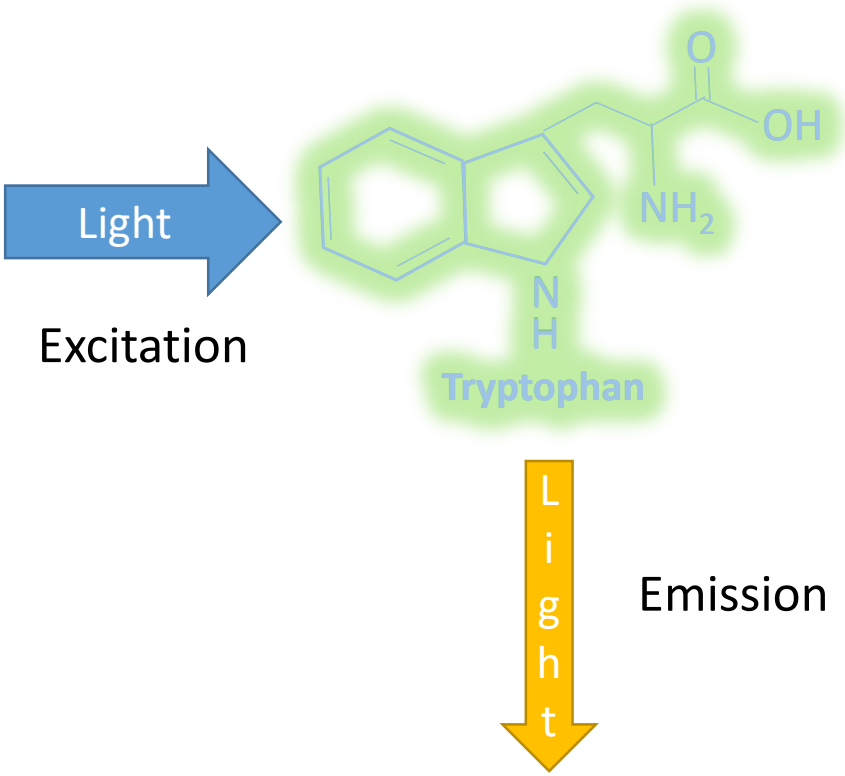
City of Houston

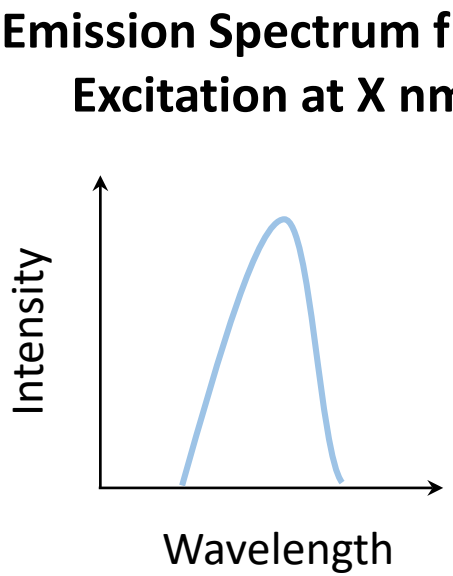
Directly serves 2.2 million

3 Surface Water Treatment Plants (~90% of supply)
56 Groundwater plants (~10% of supply)

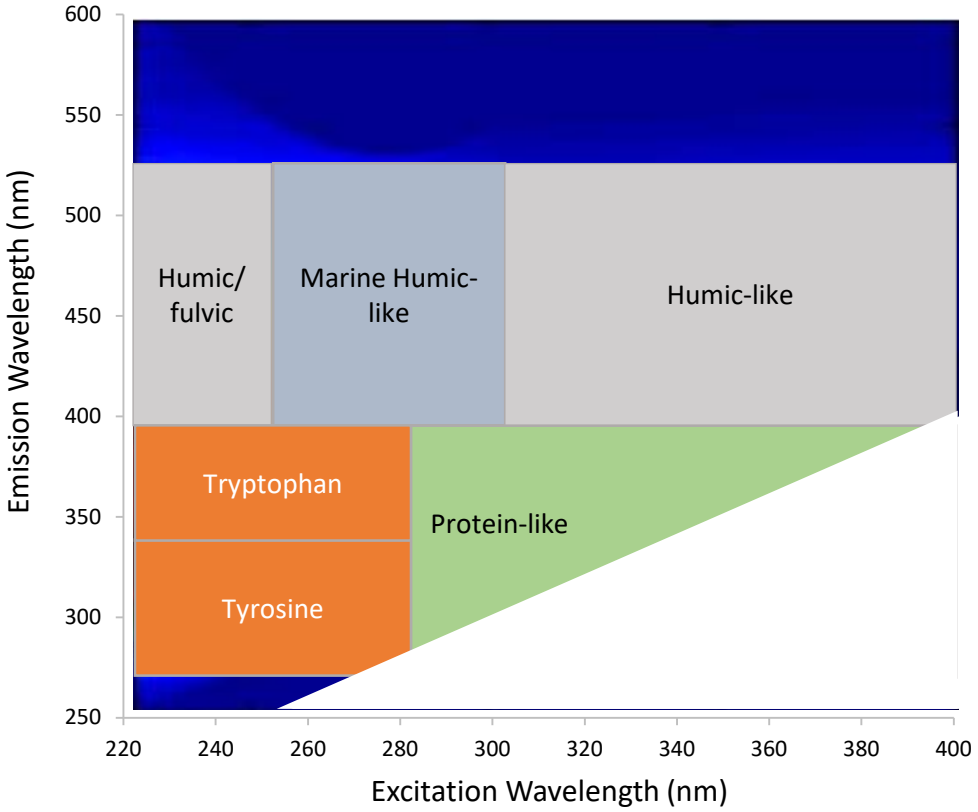
Recent nitrification events led to total coliform positives and public notifications

Fluorescence-based metrics may be applicable for early detection of nitrification





Fluorophores are classified based on their Excitation/Emission coordinates within the EEM



Fluorescence Index

$$FI = \frac{I_{370/470}}{I_{370/520}}$$

FI > 1.8 indicates predominance of microbially derived organic matter

Tryptophan and Tyrosine

Aromatic amino acids have been detected in samples from nitrifying bench-scale reactors[1]

[1]Bal Krishna et al., WR 46 (2012) 3977-3988

Commercially available submersible sensors can collect real time data at one or more Ex/Em pairs

Standard fluorescence sensors are available, targeting specific Ex/Em pairs

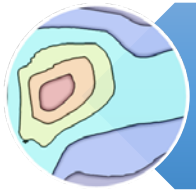
- Fluorescent Dissolved Organic Matter
- Tryptophan
- Chlorophyll
- Hydrocarbons

Sensors with custom wavelength pairs are also available

One or more sensors can be combined into a sensor package

- Fluorescence sensors
- pH
- Oxidation reduction potential

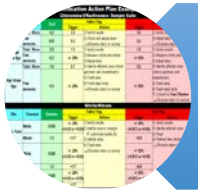
This project has 4 objectives:



Evaluate fluorescence-based metrics for detecting soluble microbial products (SMPs) associated with the onset of nitrification and signaling reestablishment of biological stability

Identify $I_{Ex/Em}$ pairs and data processing techniques suitable for detecting nitrification and acquire sensor packages

Validate sensor packages and develop data processing and sensor O&M procedures



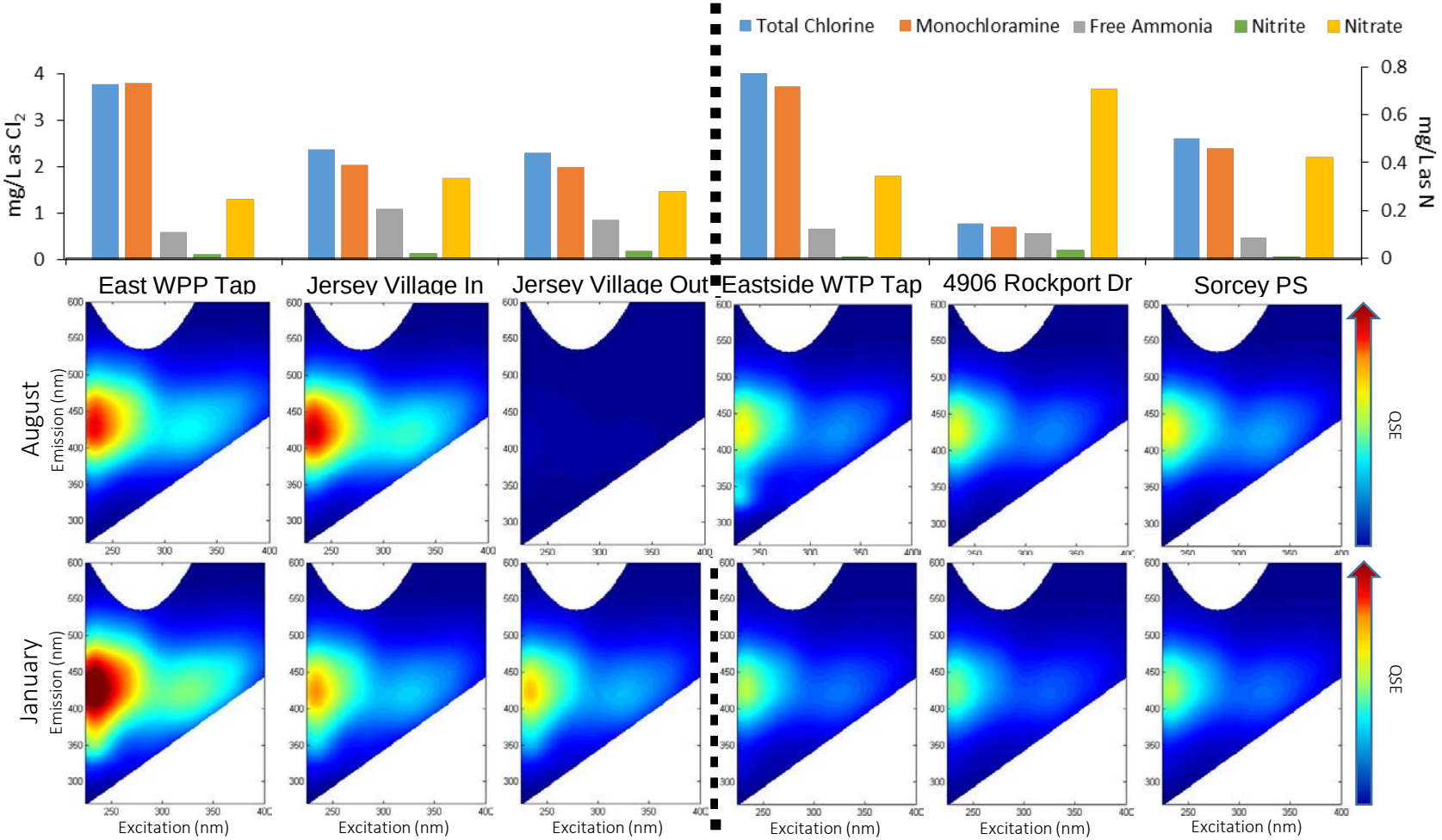
Amend existing nitrification action plans to include in situ fluorescence sensor data

Experiments to date have aimed to identify the impacts of nitrification of fluorescence EEMs

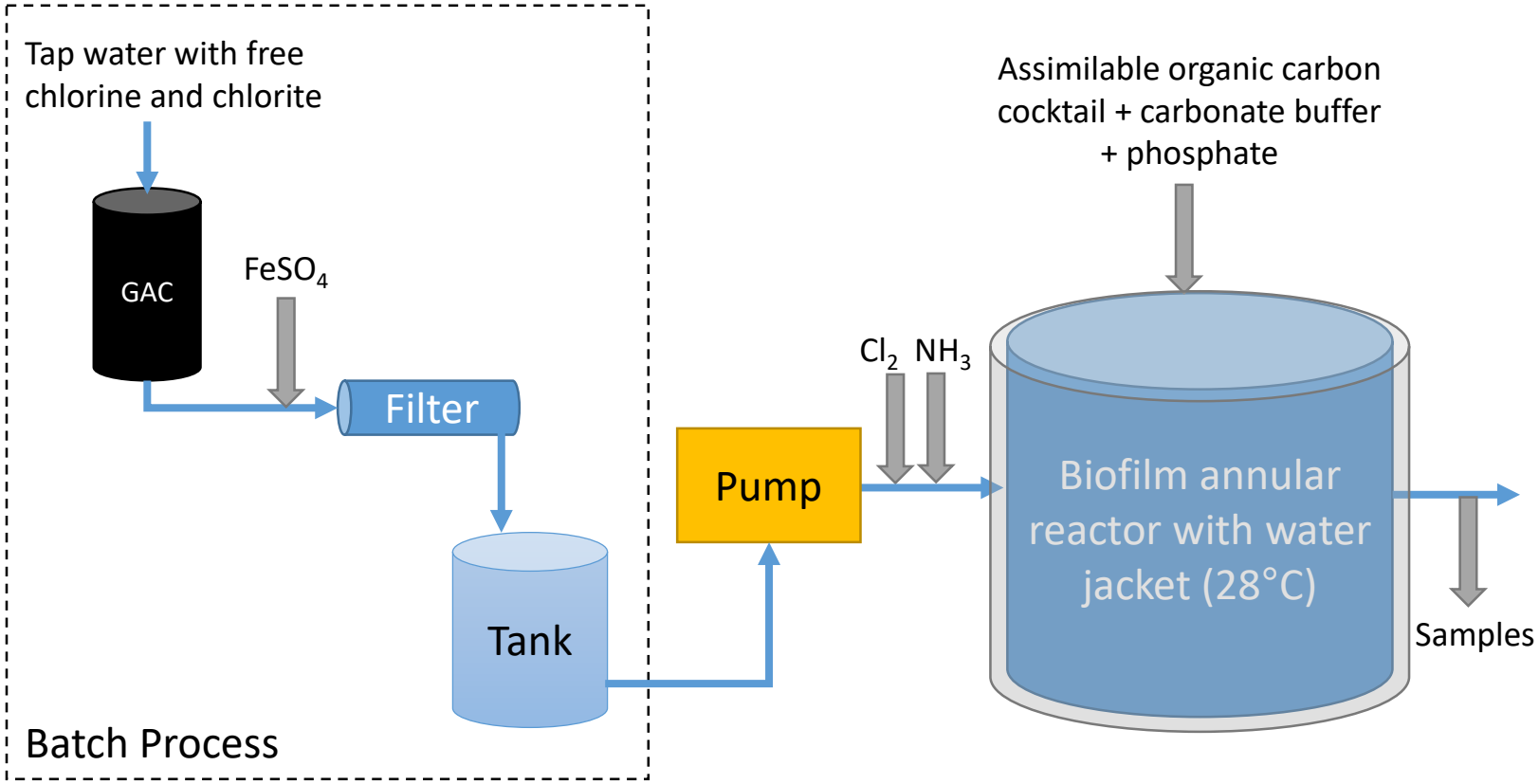
Water quality characterizations	Biofilm annular reactor (AR) experiments	Interference Testing

• Monthly distribution system sampling
• Houston: 8 sites
• Dallas: 10 sites
	• Develop nitrifying biofilm
	• Evaluate control measures
	  • Free chlorine
	  • Monochloramine
		• Impact of pH, nitrite, nitrate, iron, etc. on fluorescence data
		• Ranges based on distribution system samples and regulatory limits

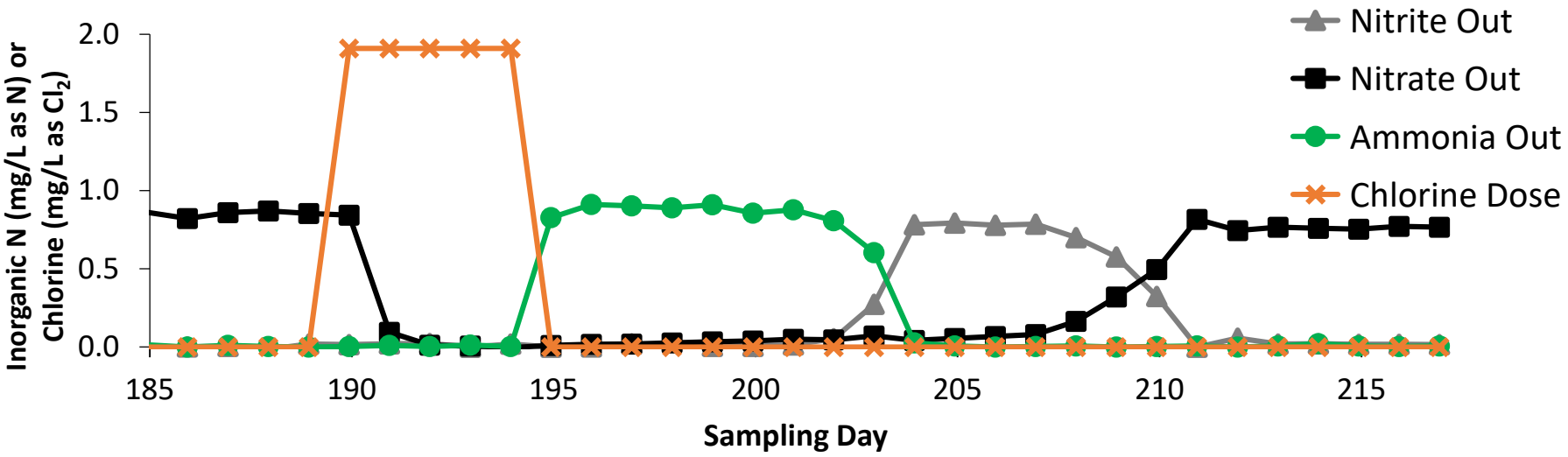
Grab sampling showed spatial and temporal variability in water quality



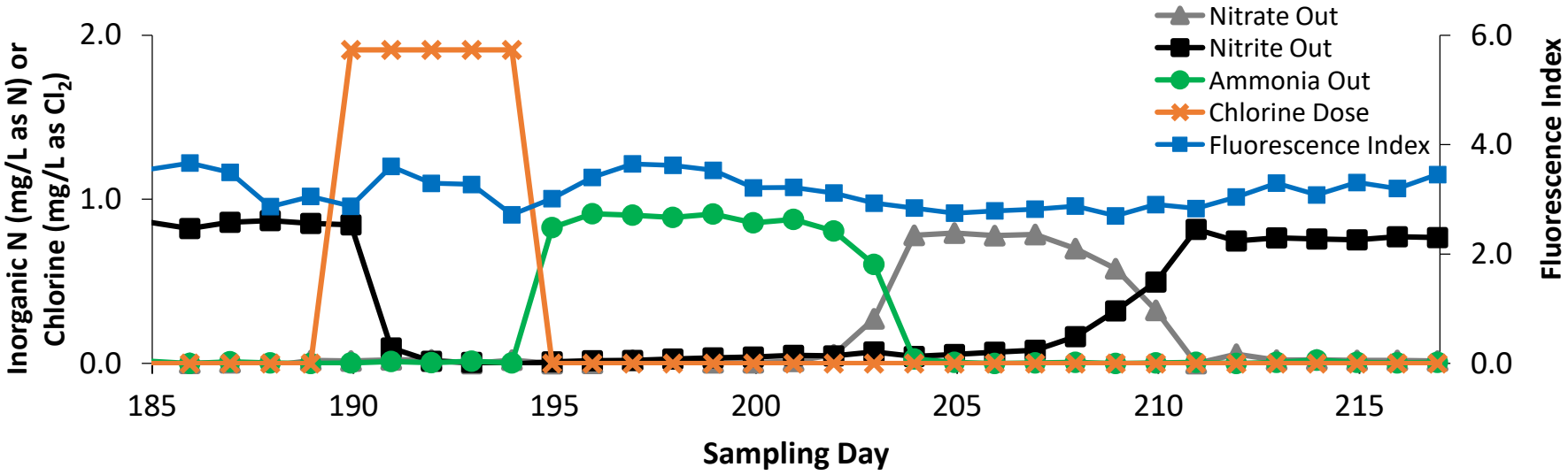
Two ARs are operated using the same source water but different chemical feeds



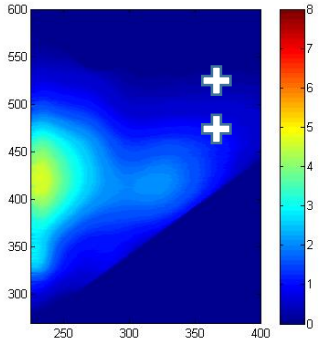
A free chlorine burn was conducted in one AR to evaluate impacts on fluorescence



Some fluorescence parameters were insensitive to nitrification

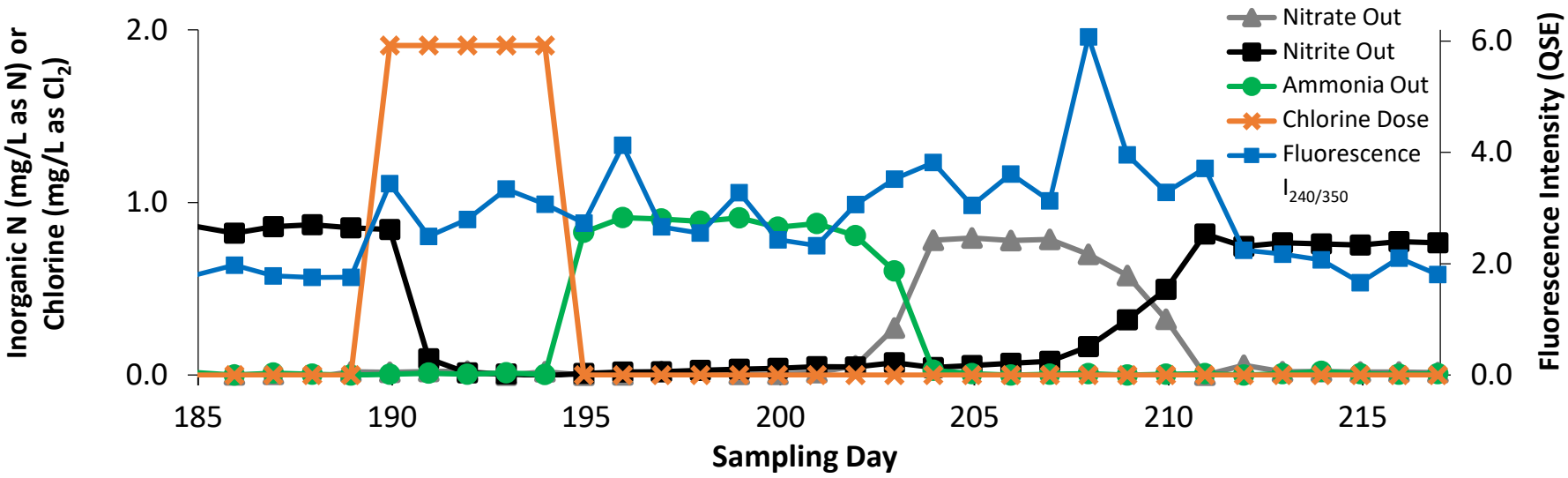


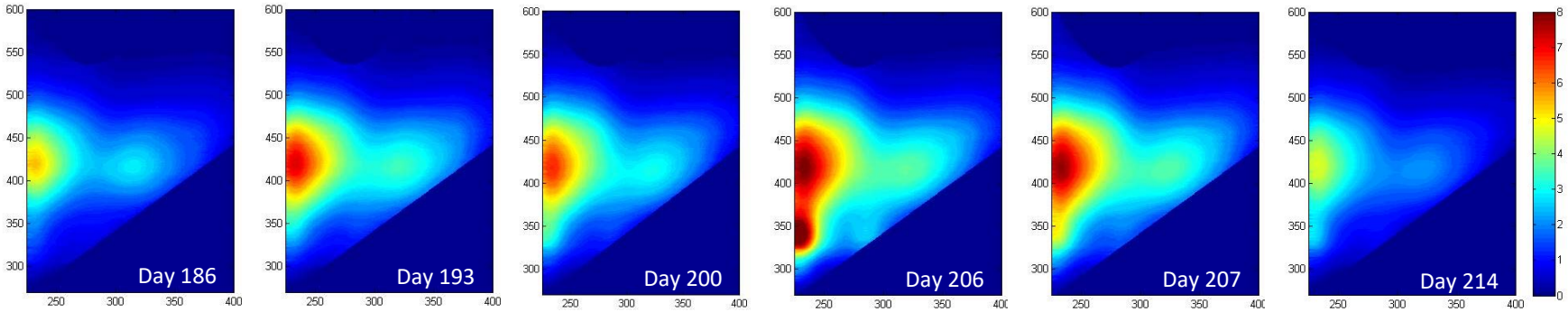
Fluorescence Index (FI) = $\frac{I_{370/470}}{I_{370/520}}$



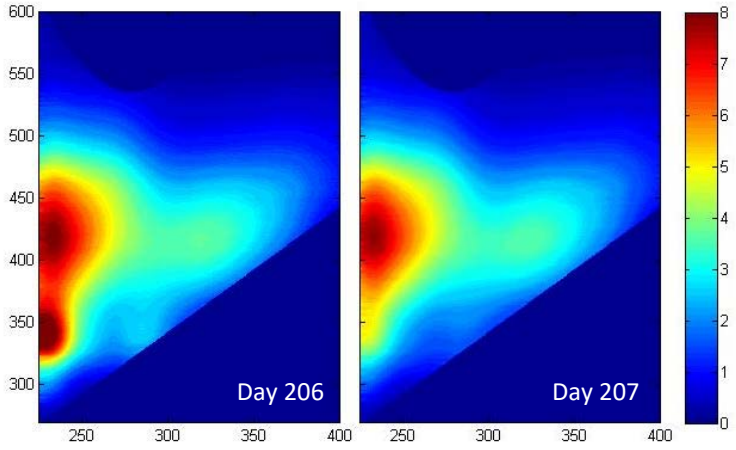
Samples dominated by terrestrially-derived organic matter have FI values near 1.3, whereas samples with predominantly microbially-derived OM have FI > 1.8.

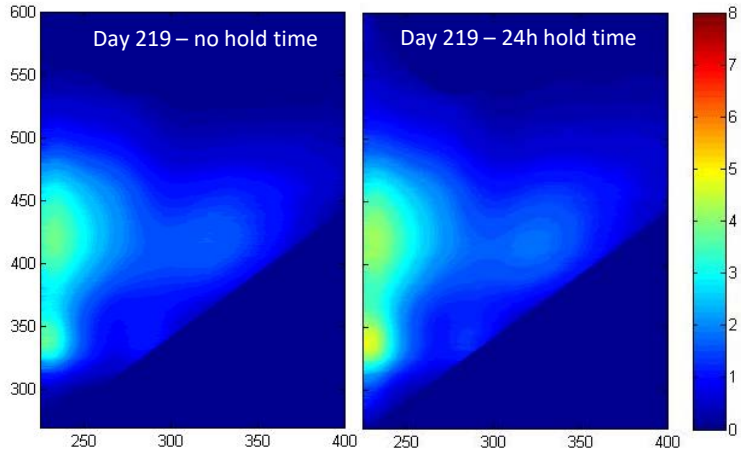
Fluorescence pairs in the tryptophan-like region were more sensitive to changes in nitrification status





The tryptophan-like fluorophore is short-lived and possibly reactive



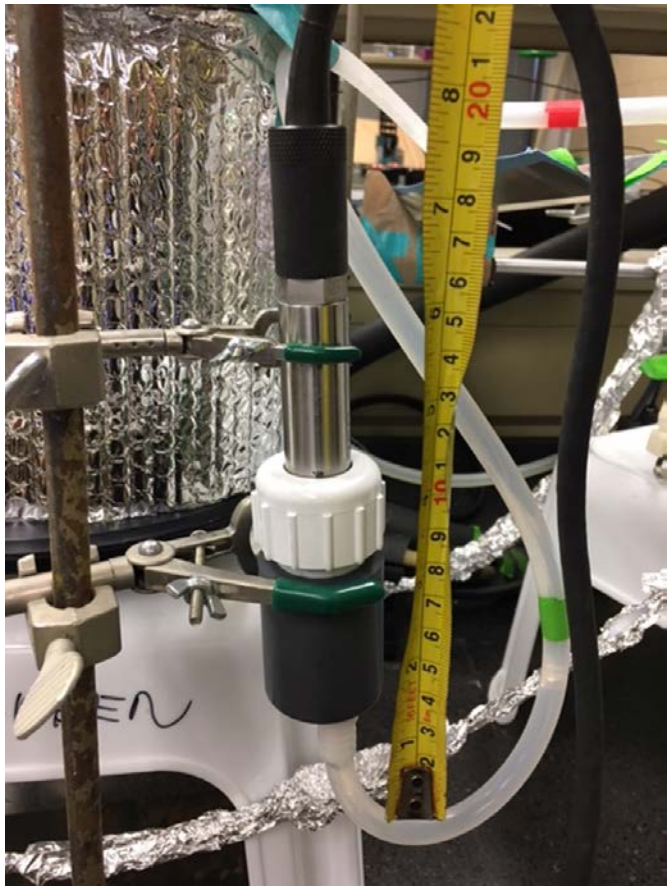


Online sensors can help define the usefulness of this peak for detecting nitrification.

Interference testing specific to this peak will be needed

A tryptophan sensor has been plumbed into the AR effluent line

- Targets Ex/Em 285/350
- Collects data every 0.5 seconds and outputs 1-minute averages
- Data will be collected as nitrification is arrested and restarted



Conclusions and next steps

A tryptophan-like peak was observed during a nitrification event in an annular reactor

Additional experiments will provide insight into this peak's applicability for online monitoring

Interference corrections are being developed as part of ongoing experiments

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