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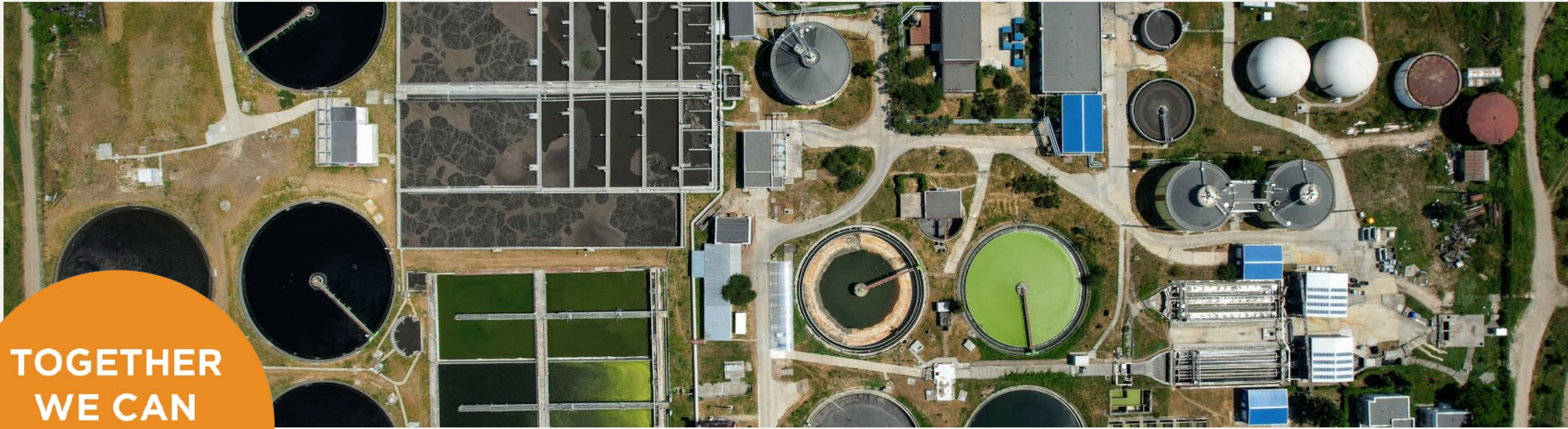

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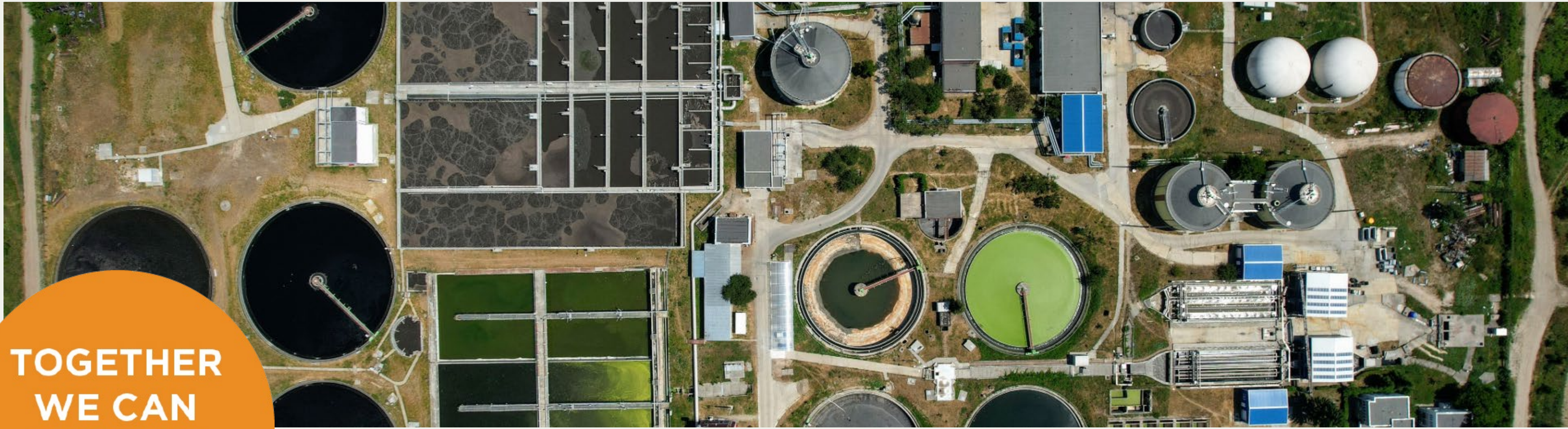

TOGETHER WE CAN MAKE AN IMPACT

WELCOME TO BERKELEY

June 3, 2025

Innovation in Wastewater Policy

Felicia Marcus
William C. Landreth Visiting Fellow
Water in the West
Stanford University

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Reverse Osmosis Concentrate Management

ANGELA STEIGLER, MODERATOR
Hazen

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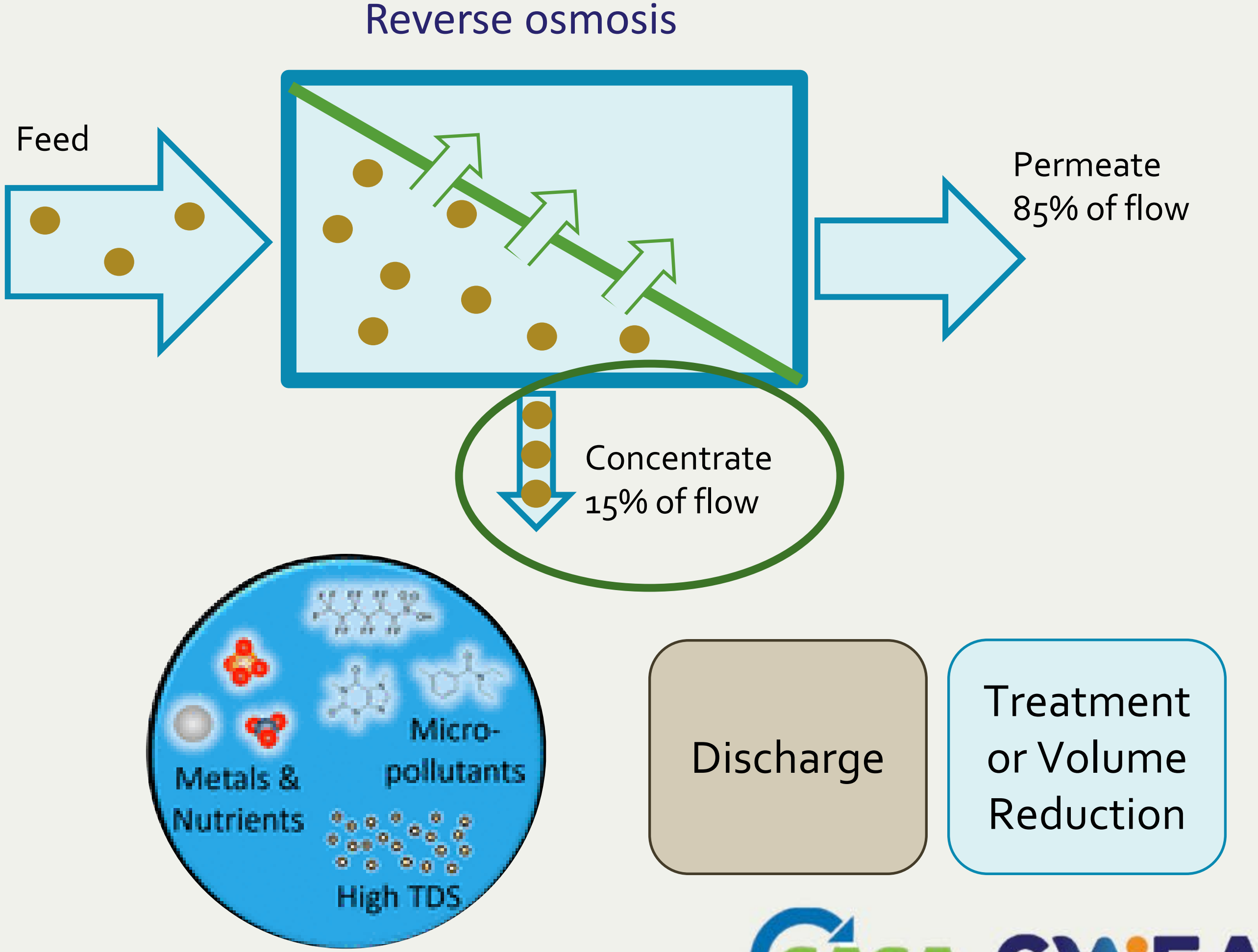
Reverse Osmosis (RO) is the leading technology for potable reuse of municipal wastewater

Modified from Finnerty et al. 2023



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Municipal Wastewater RO Concentrate Management Perspectives

Water Supply

- RO maximizes possible uses for alternative water supplies
- Incentive to maximize recoveries
- RO permeate represents a PFAS-free water supply

Wastewater Treatment

- Loads remain the same, concentrations are 5-6x higher
- Opportunity to manage contaminants in a smaller flow/volume
- Few MWRC treatability studies
- Pressure from emerging regulations

Partnering for Impact on MWROC Management

Modified from Finnerty et al. 2023

- MWROC management requires collaboration and partnership
- Opportunities for research and innovation to:
  - Reduce costs
  - Maximize benefits
  - Meet regulatory goals

Our Panelists

Manisha Kothari

Alternative Water Supply
Program Manager
SFPUC

David Sedlak

Professor of Civil & Environmental Engineering; Director of the Berkeley Water Center
UC Berkeley

Mark Donovan

North American Water Treatment and Desalination Lead
GHD

CASA CWEA

Roundtable Discussions

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Nutrient Removal – Energy Emissions Nexus

SARAH DESLAURIERS, MODERATOR
CASA

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Nutrients in Wastewater

Wastewater Treatment Removes Nutrients to Protect Receiving Waters

- Treatment needs vary from plant to plant
- Treatment operations can be energy-intensive
- Treatment may require chemical addition (chemical production can be energy-intensive)
- Integrating new technology must look at up- and down-stream impacts
- Increased intensity of treatment or changes to operations to enhance nutrient removal can lead to increased emissions

- Must look at the big picture to understand net impact

Optimize Nutrient Removal, Energy, & Emissions!

- Nutrient removal is a top priority for the State and Regional Water Boards
- Carbon neutrality is a top priority for the Air Resources Board

- National research has been underway for decades on each topic
- California and Denmark have a partnership to share information on the water-energy-emissions nexus work at Aarhus Vand (and others)
- CASA Research Collaborative is working to bring partners together in CA

Our Panelists

Dr. Mike Falk

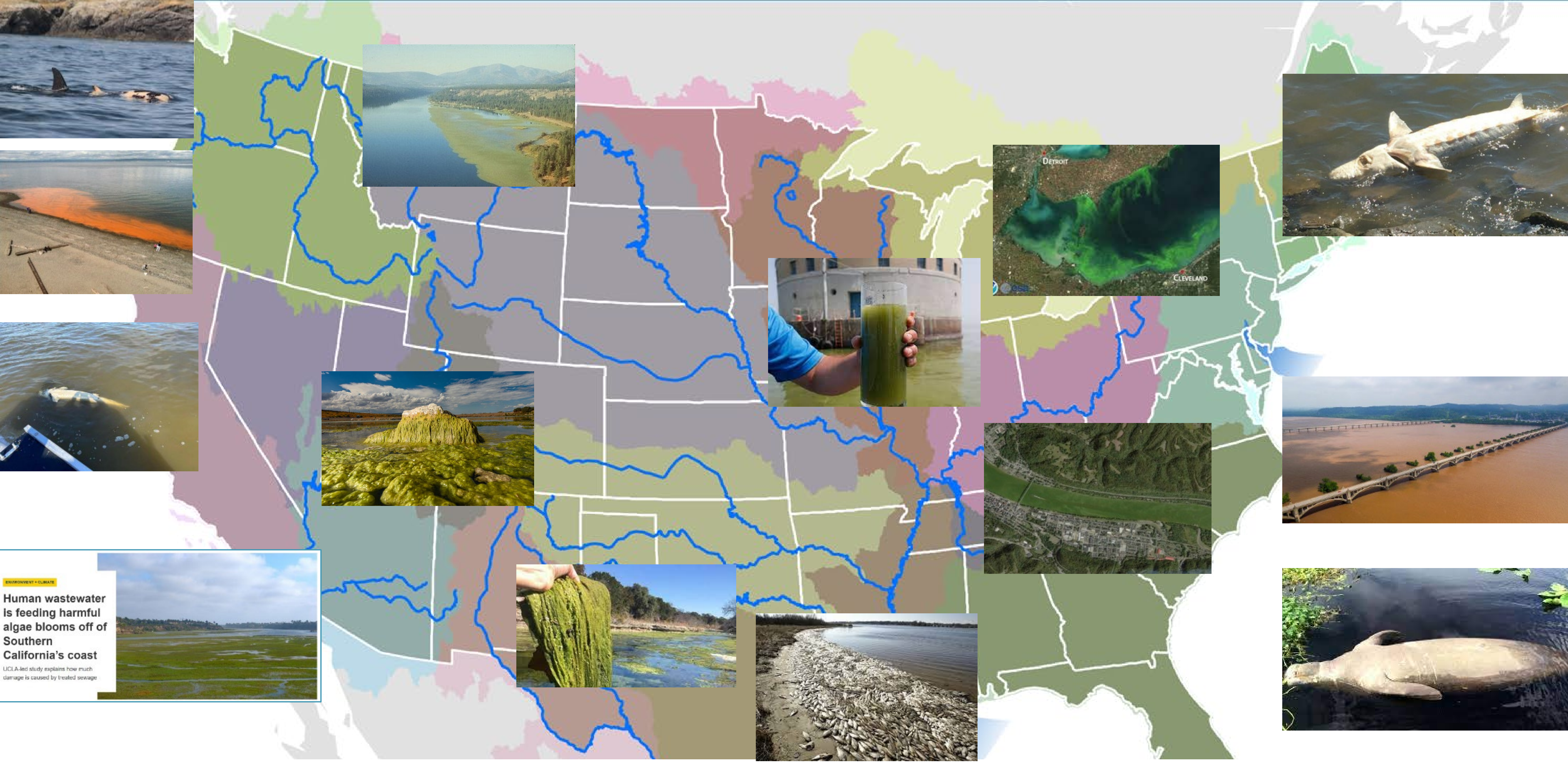
Approaches to
Nutrient Removal
HDR

Dr. Krishna Pagilla

Nitrogen Removal Treatment
– Energy & Nitrous Oxide
Emissions,
University of Nevada - Reno

Christophe Boisvert

Monitoring Nitrogen Removal for
Performance Optimization at Aarhus
Vand (Denmark) & Utilizing Data
through Digital Twin Modeling,
DHI



- **IMPAIRMENT OF AESTHETICS, RECREATION, AQUATIC LIFE, AND WATER SUPPLY**
- **STRATEGIC TO “SQUEEZE THE PIPES” MORE EFFECTIVELY**

Drivers Specific to California

- Algae Blooms (Freshwater and Brackish)
  - Bay Area: 2022/2023
  - SoCal Bight
  - Freshwater
- Ocean Acidification (related to Algae)
- Depressed Dissolved Oxygen Levels
- Public Health: Blue-Baby Syndrome
- Freshwater Mussels
- Others

r/socalhiking • 4 yr. ago
puphenstuff

So now they suspect Toxic Algae killed 3 hikers and a dog??? WTF?

With the historic drought, I imagine toxic algae might occur anywhere. I don't think these hikers ever swam in the water (I may be wrong). I think the implication is that just hiking near a stream can instantly kill you and your family? Has this happened before in California?

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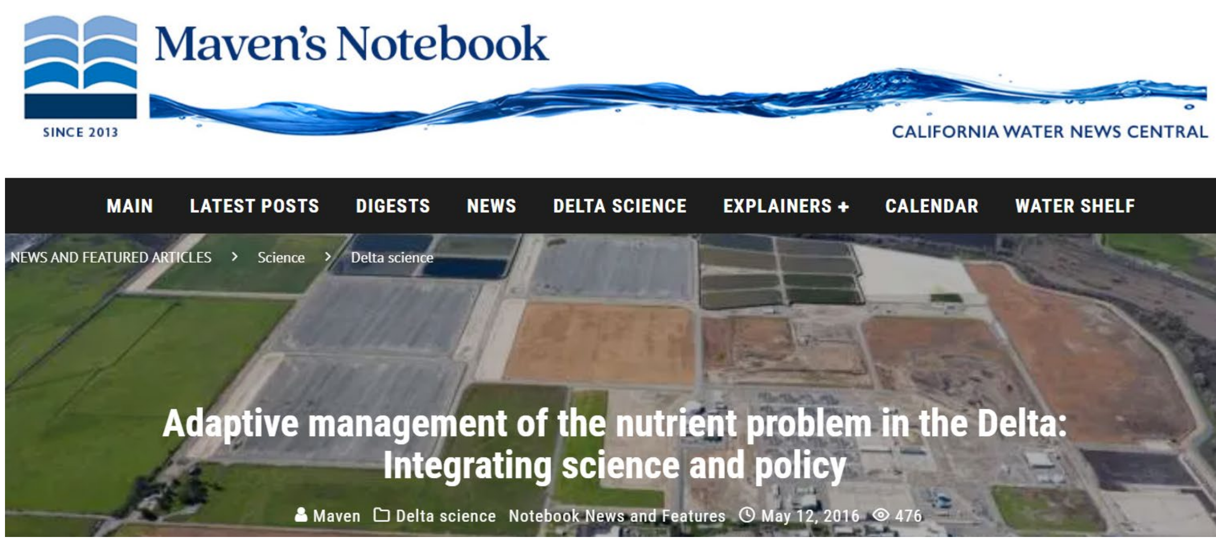
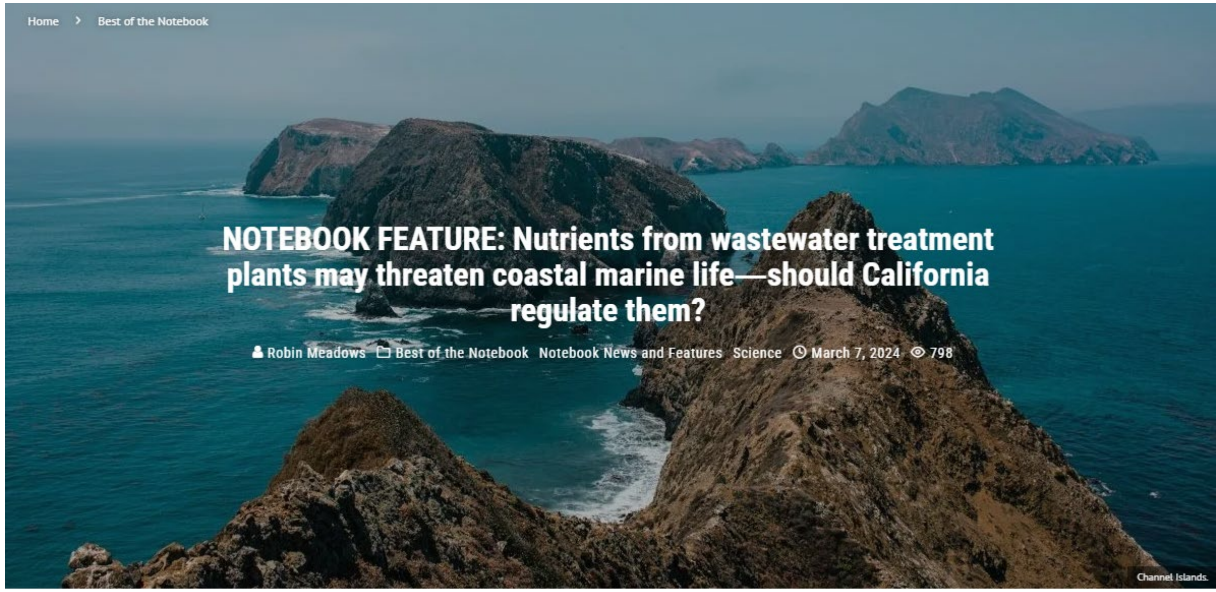
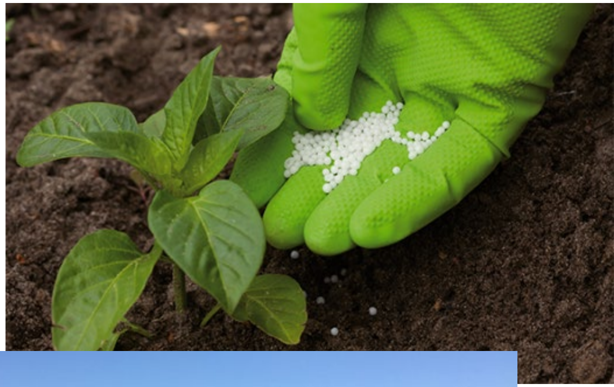




Nutrients from human waste boost ocean acidification & hypoxia in CA—wastewater treatment agencies say regulation is premature, environmentalists say it's overdue & researchers say it's "fair to ask hard questions" about the science.

On-Going and Future Treatment Themes

- **<u>Treatment and Process (How to “Squeeze” More Out of the Pipes):</u>**
  - Optimization
  - Sidestream Treatment
  - Upgrades
  - Process Intensification
  - Resource Recovery

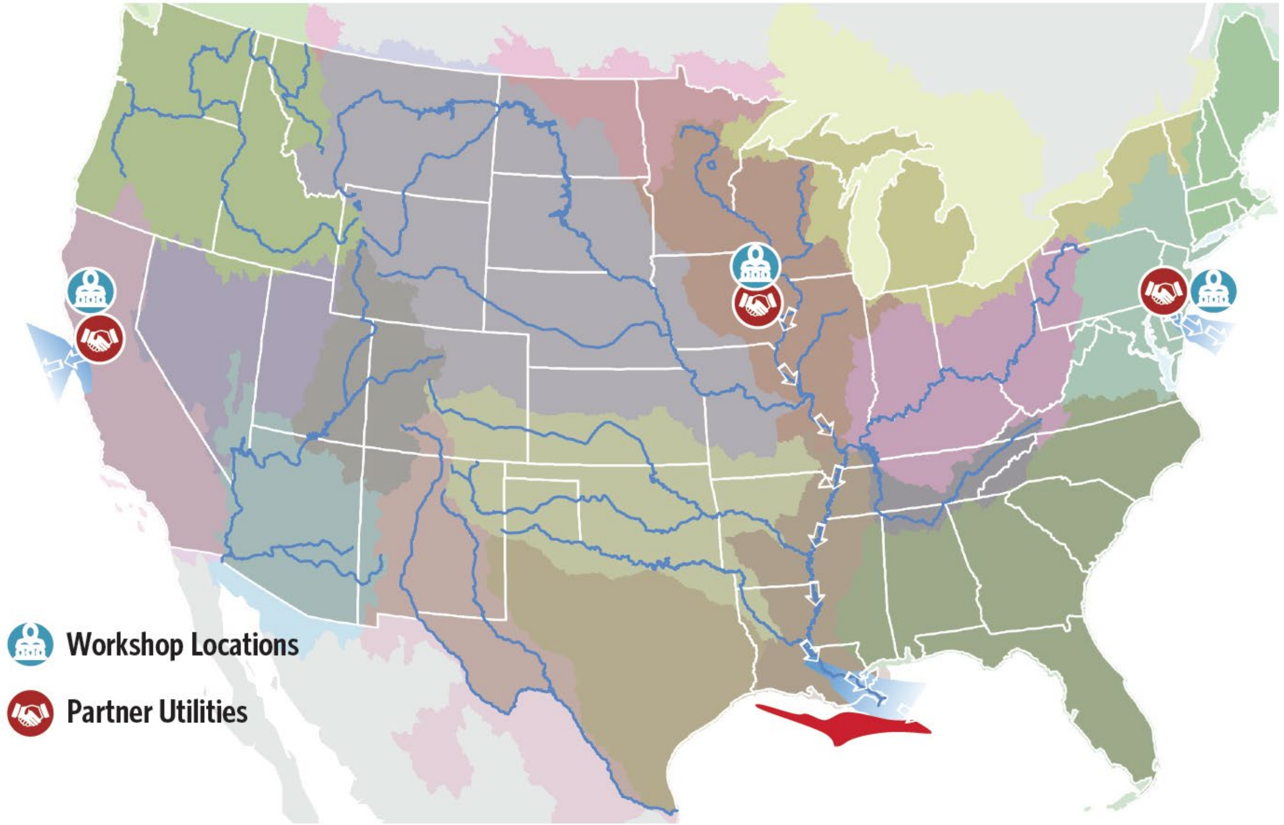


- **<u>Supply/Reuse:</u>** Potable Reuse (refer to Reverse Osmosis Conc Challenges Discussion)

- **<u>By Other Means:</u>** Reuse, Nature-based Solutions, etc.
- **<u>Non-Point Source Loads:</u>** Agriculture, Stormwater, etc.

Blueprint for Regional Approaches : Holistic Approach to Improved Nutrient Management: Phase 1 WRF #4974

Figure 1. US Watersheds and Strategic Locations of Partner Utilities and Workshop Locations



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BACWA BAY AREA CLEAN WATER AGENCIES

CEDAR RAPIDS City of Five Seasons

IOWA SOYBEAN Association

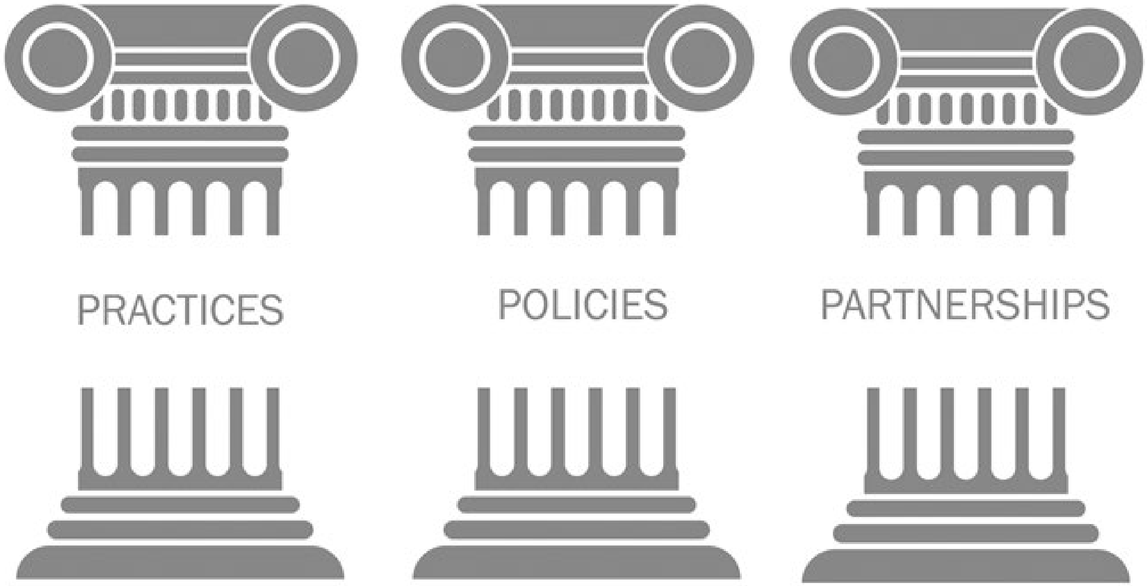
PHILADELPHIA WATER DEPARTMENT

[Holistic Approach to Improved Nutrient Management | The Water Research Foundation (waterrf.org)]

Holistic Pollution Management: Practices, Policies, and Partnerships (3 P's)

THE Water Research FOUNDATION

Key Factors Influencing Holistic Nutrient Mgmt



- Practices
  - Treatment
  - Best Management Practices
- Policies
  - Regulatory Frameworks
  - Watershed Governance
- Partnerships
  - Collaboration
  - Leadership

Regional Approaches: Balance the 3 P's to Incentivize Cost-Effective and Beneficial Regional Solutions

BACWA BAY AREA CLEAN WATER AGENCIES

BACWA (wastewater utilities)

CALIFORNIA Water Boards

Regional Water Board (regulatory)

SFEI AQUATIC SCIENCE CENTER
SAN FRANCISCO ESTUARY INSTITUTE & THE AQUATIC SCIENCE CENTER

San Francisco Estuarine Institute (science)

SAN FRANCISCO BAYKEEPER®

Non-Govt Organizations (NGOs)

University of Nevada, Reno

Nitrous Oxide Emissions from WRFs during N Removal

Krishna Pagilla, PhD, PE, BCEE

Ralph & Rose Hoeper Endowed Professor

Director, Nevada Water Innovation Institute

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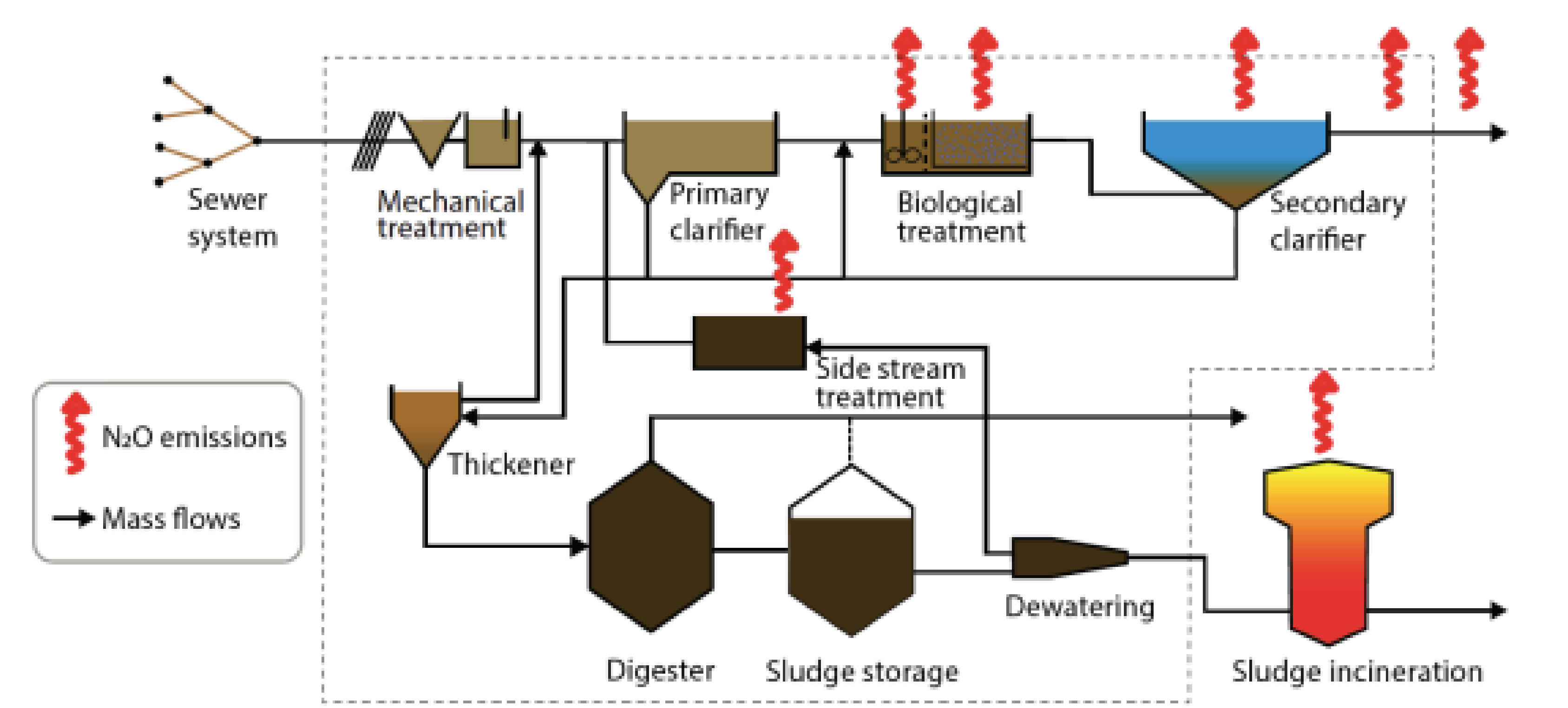
Nitrous Oxide (N_2O) Emissions and Aeration Energy in N Removal

- N_2O is emitted from:
  - Biological N Removal Process
  - Secondary Treatment
  - Discharged Effluent

- Overall WRF Carbon Footprint
  - >50% Energy for Aeration (Scope 2)
  - Nitrification Doubles Aeration Demand
  - Sidestream Treatment Increases Energy Demand



Possible Nitrous Oxide (N_2O) Pathways

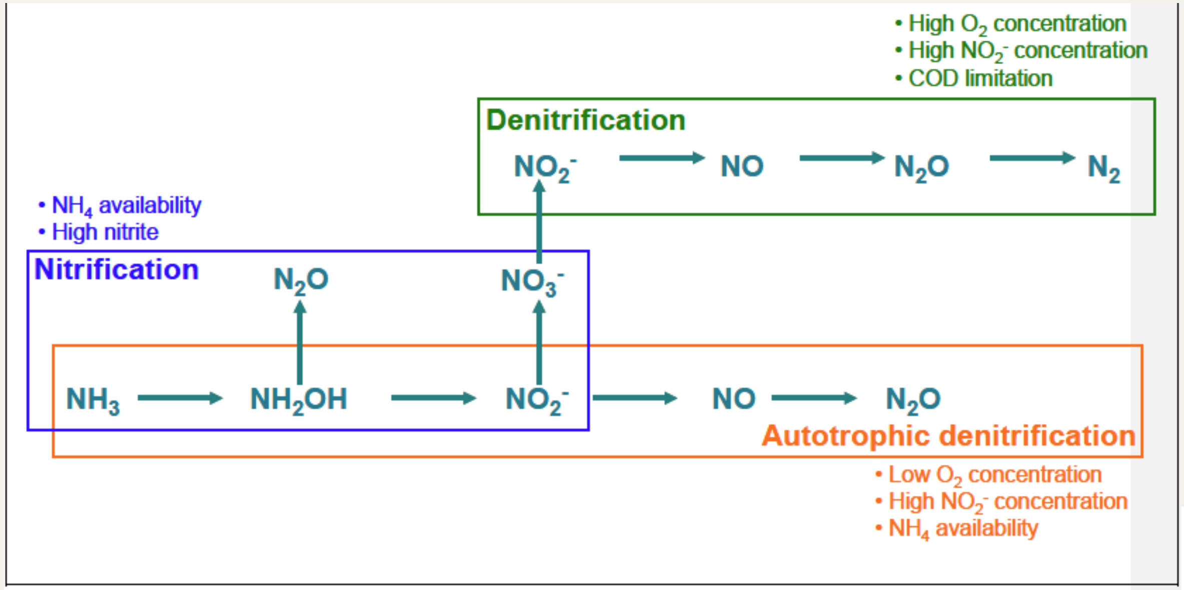
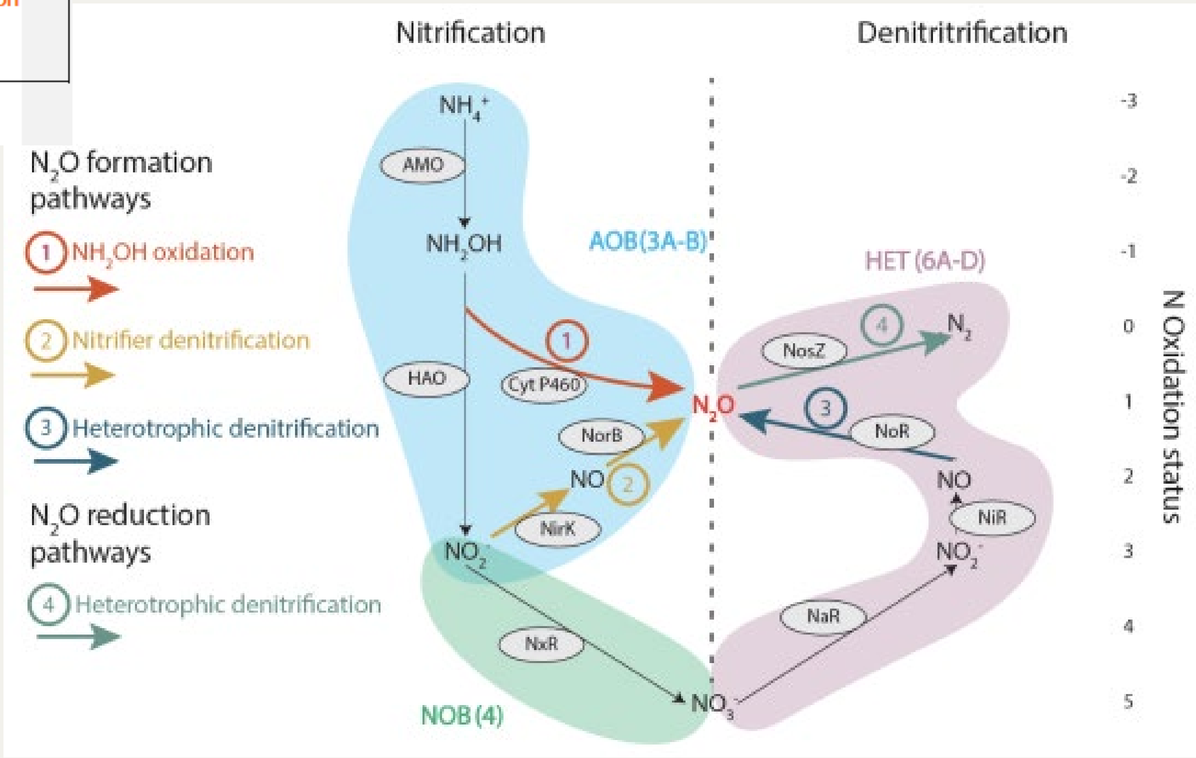


Figure 1 Schematic overview of the possible routes of N_2O emission and the process parameters that were found to influence the formation of N_2O.

Ref. STOWA 2011



Influencing Factors:

1. High NH_4-N and High NO_2-N in Nitrification
2. Low DO, High NO_2-N, and NH_4-N Availability in Autotrophic Denitrification
3. High DO, High NO_2-N, BOD/COD Limitation in Heterotrophic Denitrification

N_2O Emissions from Activated Sludge

(Ahn et al., 2010. EST; Ahn et al., 2010, WER; Rassamee et al., 2011, B&B)

National Study Funded by Water Environment Research Foundation (WERF U4R07; 2008-2009)

- More N_2O emissions observed from aerobic vs anoxic conditions
- High variability across WRFs and diurnally within each WRF
- Single emission factor for all WRFs is not appropriate
- High Nitrite, Ammonium, and DO concentrations were positively correlated to N_2O Emissions; other factors may play an indirect role
- BNR processes that minimize transient conditions and achieve complete N removal (low TN effluents) are likely to have lower N_2O emissions
- More facility-level research needed

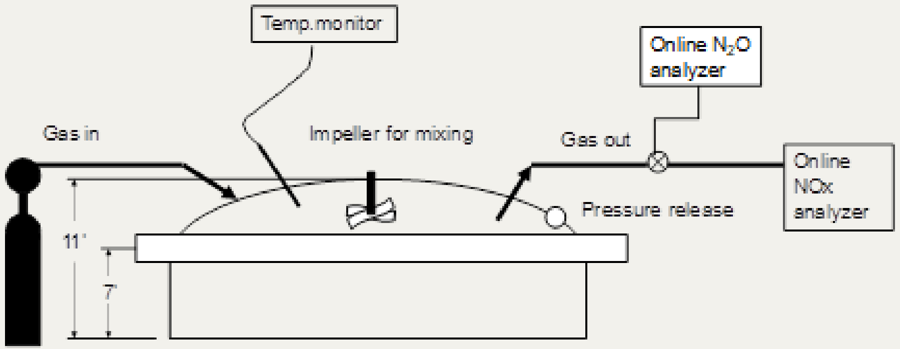
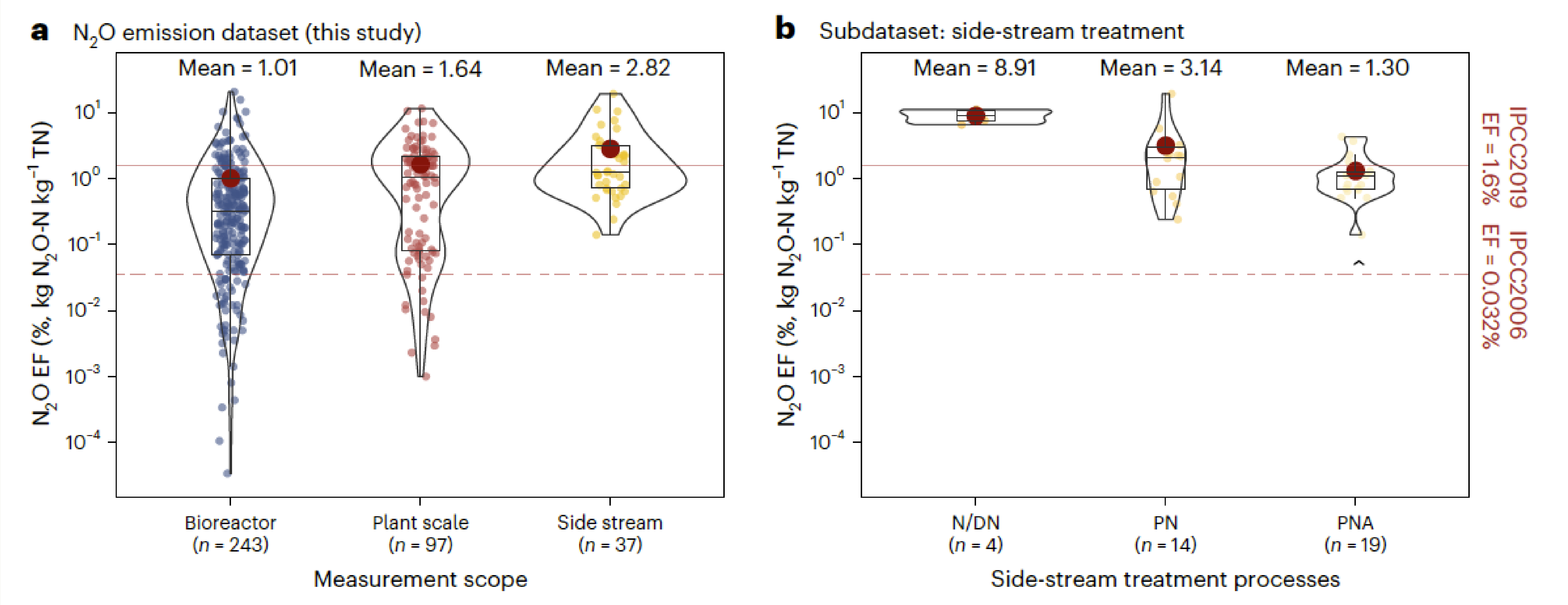


Table I: Summary of N_2O fluxes and emission factors measured at full-scale WWTPs

Plant Configuration	Temp(°C)	Q (MGD)	% influent TKN emitted as N_2O	% TN removed emitted as N_2O	Emission factor (g N_2O/PE/yr)
Separate-stage BNR	15 ± 0.48	23	0.03 ± 0.00	0.03 ± 0.01	1.2 ± 0.18
	23 ± 0.28	27	0.01 ± 0.00	0.01 ± 0.00	0.28 ± 0.13
Four-stage Bardenpho	14 ± 0.26	7.8	0.16 ± 0.10	0.19 ± 0.12	9.8 ± 6.1
	23 ± 0.20	8.1	0.60 ± 0.29	0.66 ± 0.32	33 ± 16
Step-feed BNR 1	19 ± 0.22	29	1.6 ± 0.83	2.9 ± 1.5	92 ± 47
	25 ± 0.28	30	0.62 ± 0.27	0.90 ± 0.39	33 ± 14
Step-feed non-BNR	17 ± 0.12	71	0.18 ± 0.18	0.37 ± 0.36	13 ± 13
	26 ± 0.81	93	1.8 ± 0.79	3.3 ± 1.5	97 ± 43
Separate centrate*	30 ± 2.3	2.0	0.24 ± 0.02	0.63 ± 0.06	*
	34 ± 0.32	1.6	0.54 ± 0.16	0.96 ± 0.32	*
Plug-flow 1	11 ± 0.20	18	0.40 ± 0.14	0.92 ± 0.32	23 ± 7.9
	23 ± 0.46	15	0.41 ± 0.14	0.70 ± 0.24	28 ± 9.6
Plug-flow 2	11 ± 0.41	8.7	0.62 ± 0.15	1.7 ± 0.41	26 ± 6.4
	22 ± 0.58	6.6	0.09 ± 0.03	0.22 ± 0.06	5.0 ± 1.4
MLE 1	26 ± 1.8	4.0	0.07 ± 0.04	0.09 ± 0.05	6.8 ± 3.5
MLE 2	26 ± 0.17	4.1	0.06 ± 0.02	0.07 ± 0.03	5.4 ± 2.0
Step-feed BNR 2	29 ± 0.18	14	1.5 ± 0.02	1.7 ± 0.02	140 ± 1.2
Oxidation ditch	19 ± 0.58	3.4	0.03 ± 0.01	0.03 ± 0.01	1.8 ± 0.77
Step-feed BNR 3	24 ± 0.78	57	0.05 ± 0.03	0.06 ± 0.03	4.1 ± 2.2

Key Findings from Recent Work* (2024)

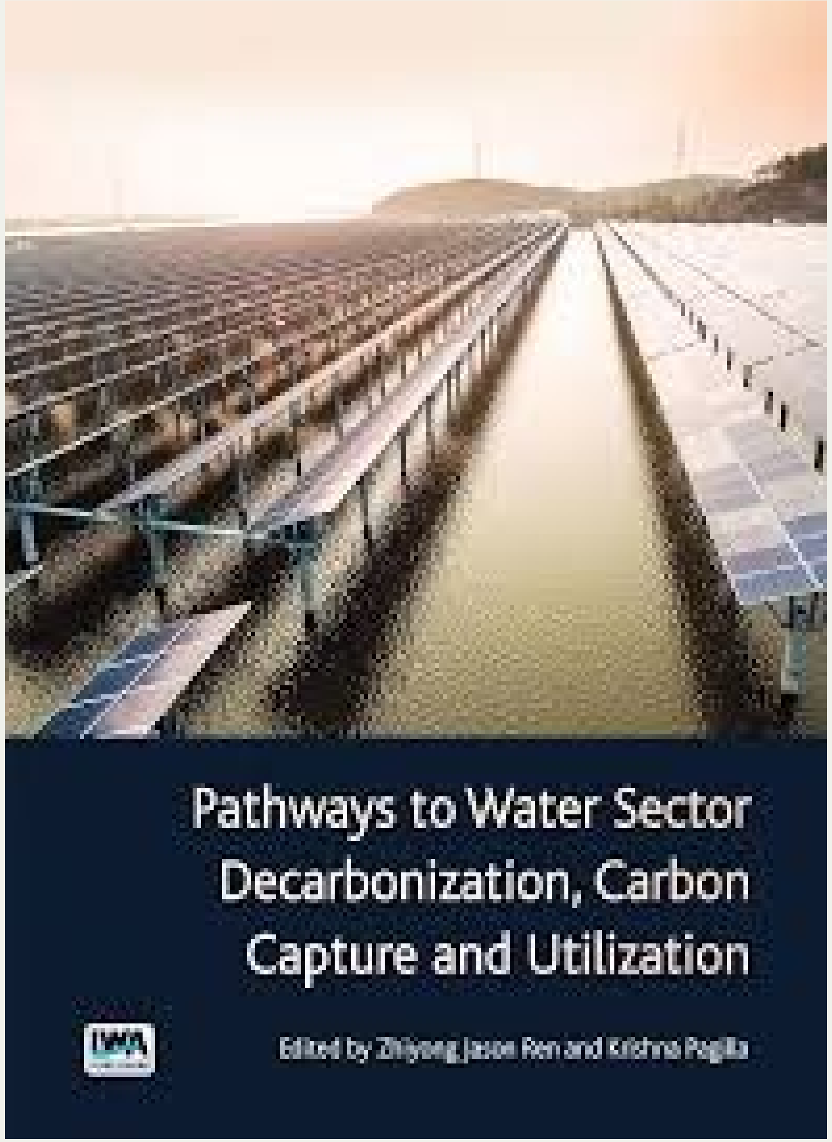
The results reveal the diverse nature of wastewater N_2O emissions and underscore the need for a customized approach to inform facility-level N_2O emission estimation as well as inform national- and sector-wide GHG inventories with emphasis on site-specific considerations.



Oversimplification and Mis-estimation of Nitrous Oxide Emissions from Wastewater Treatment Plants, 2024* – Cuihong Song, Jun-Jie Zhu, John Willis, Daniel Moore, Mark Zondlo, **Zhiyong Jason Ren, Nature Sustainability

Key Insights

- BNR at WRFs emit N_2O at various levels – Variability is common!
- Need facility-level approach for accurate estimation and N-removal process selection
- Many process factors (temperature, DO, pH, ammonium levels, C/N Ratio, aeration rate/type, and transient conditions) are responsible – <u>DO and Transient Conditions</u> are dominant factors for N_2O emissions
- Low TN plants have lower risk of N_2O emissions
- Understanding N_2O emissions at a facility is directly related to understanding the BNR operations and performance
- N_2O emissions in WRFs may constitute majority of total direct (Scope 1) GHG emissions if not optimized



Predicting And Mitigating N_2O Emissions In WWTPs
Can Digital Twins Help Achieve Carbon Neutrality?

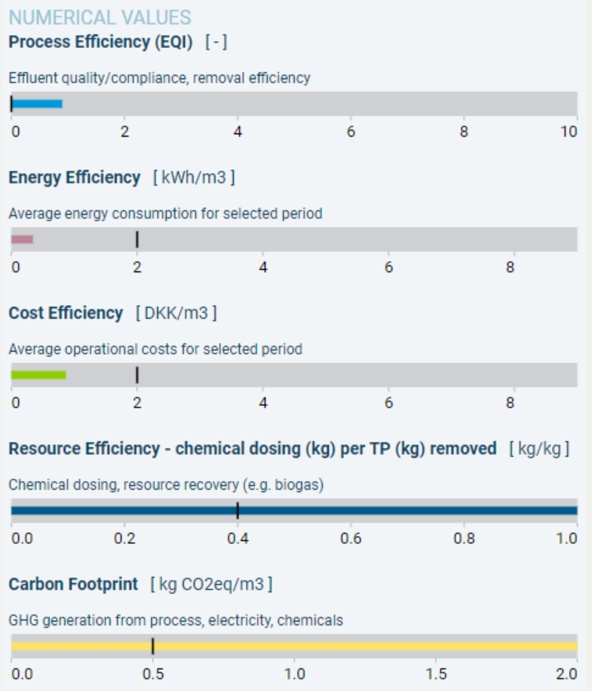
Christophe Boisvert, DHI
Carles Pellicer-Nàcher, F. Polesel, M. Rebsdorf, A. Lynggaard-Jensen, E. Brodersen, M. Guldborg Hansen, P. Andreasen, T. Dalkvist

mudp
fors
aarhusvand
DHI

Digital twins: why?

Benefits in the context of N_2O mitigation:

- Analyse and contextualize complex N_2O process data
- Soft sensoring to decipher N_2O production mechanisms
- From data to action – mitigation of N_2O emissions



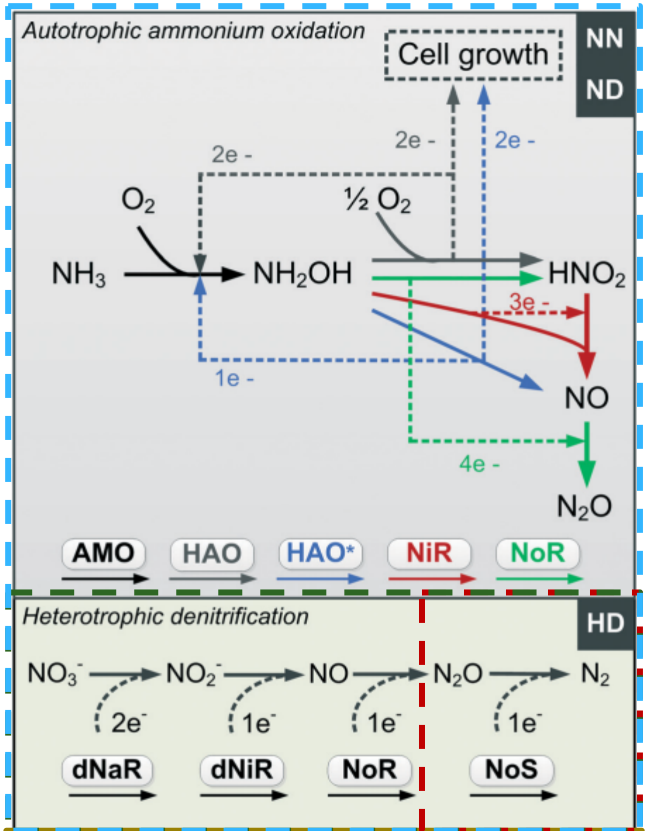
Source: https://www.controleng.com/articles/digital-twin-improves-plant-design-and-operational-performance/

Source: https://albertawater.com/influences/wastewater-treatment-plants/

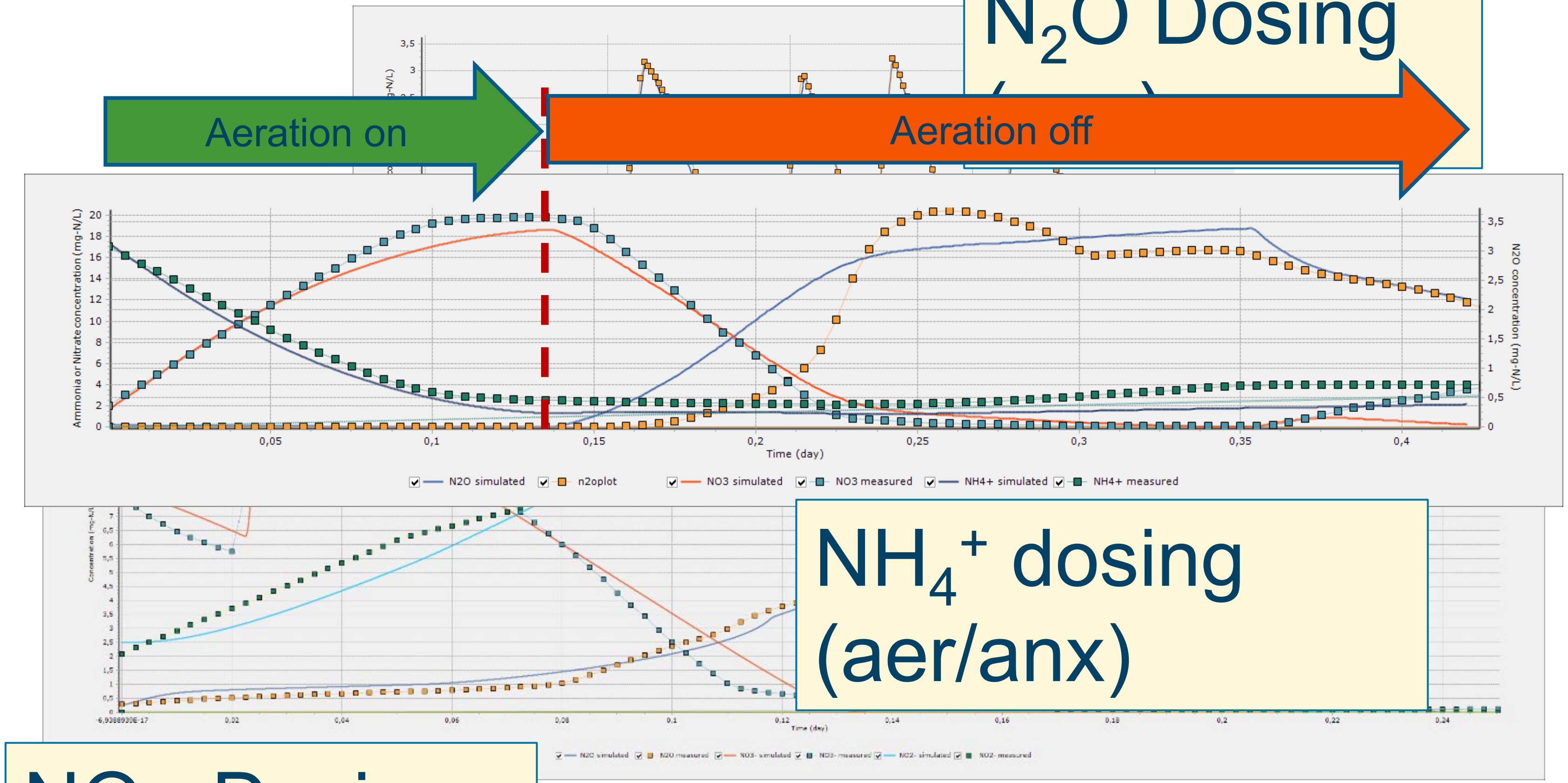
Source: https://www.forecastr.co/blog/time-series-forecasting-model

Calibration - (Marselisborg, batch mode pilot plant)

aarhusvand



No significant abiotic N_2O production



N_2O Dosing

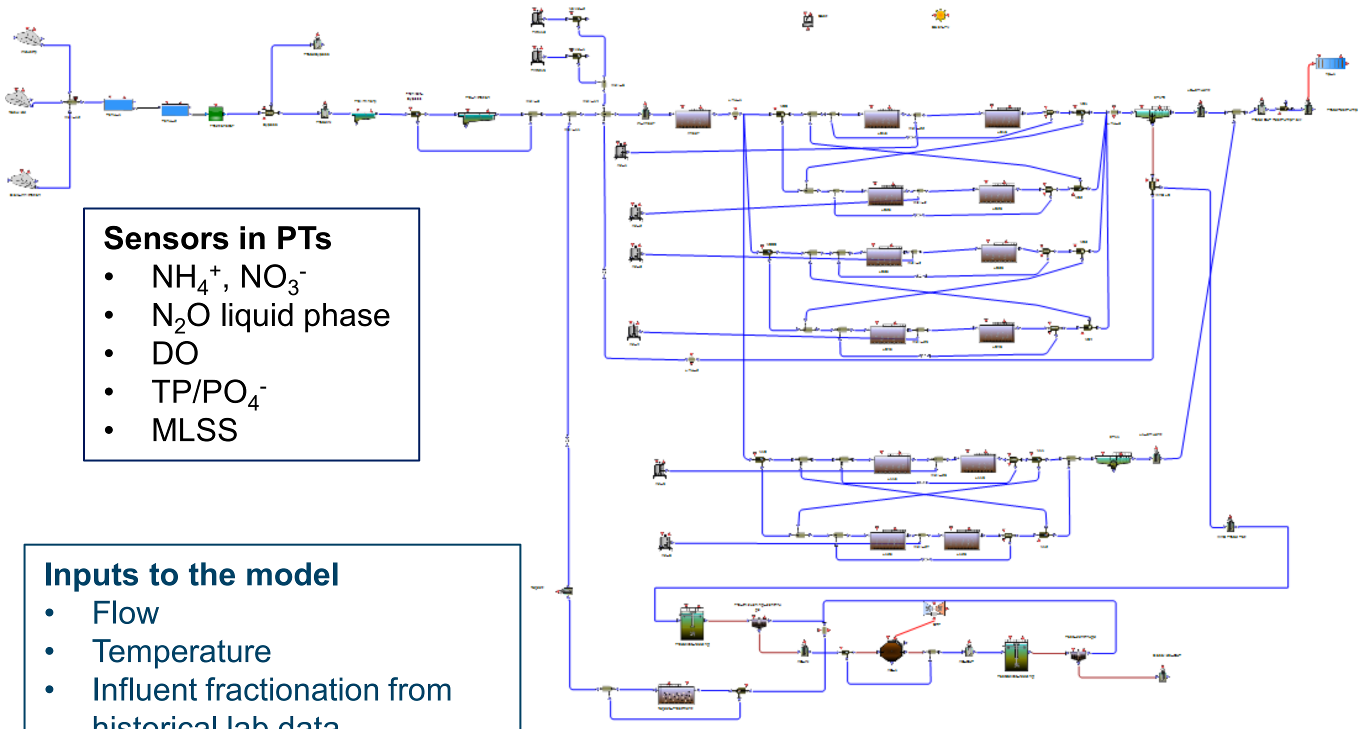
NH_4^+ dosing (aer/anx)

NO_3^- Dosing (anx)

DHI

Validation – full scale WWTP (Bjergmarken)

Controllers
- Aeration:
  - Alternating inlet/outlet and N/DN
  - Ammonia-based DO set-point
- RAS recirculation
- Sludge wastage

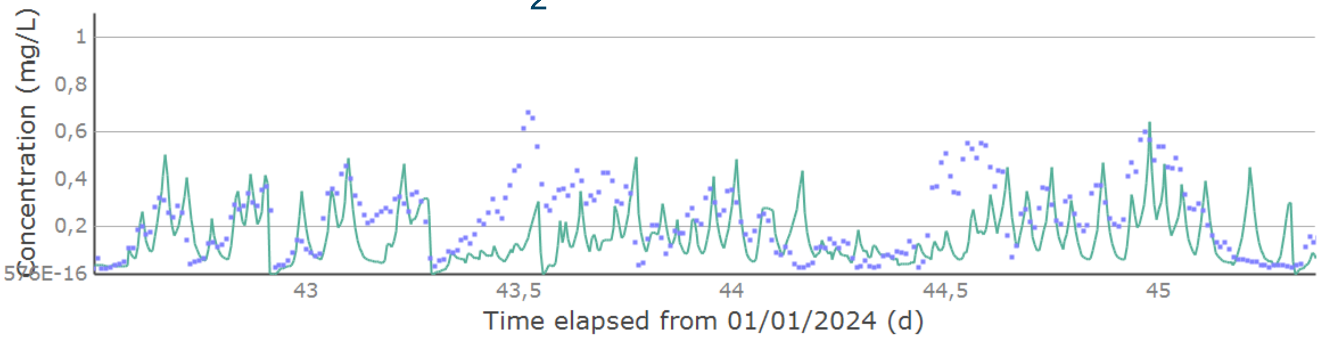


Sensors in PTs
- NH_4^+, NO_3^-
- N_2O liquid phase
- DO
- TP/PO_4^-
- MLSS

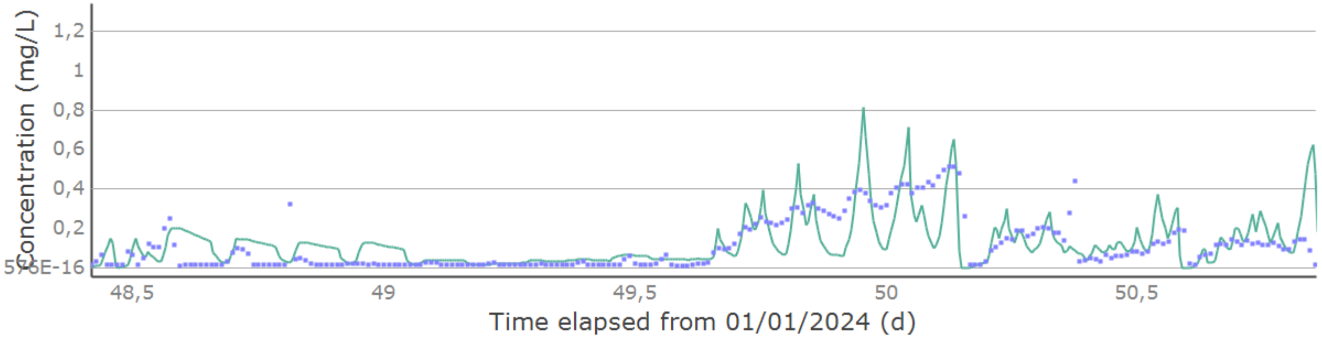
Inputs to the model
- Flow
- Temperature
- Influent fractionation from historical lab data
- RAS flows
- 3-digits phase codes for alternating N/DN

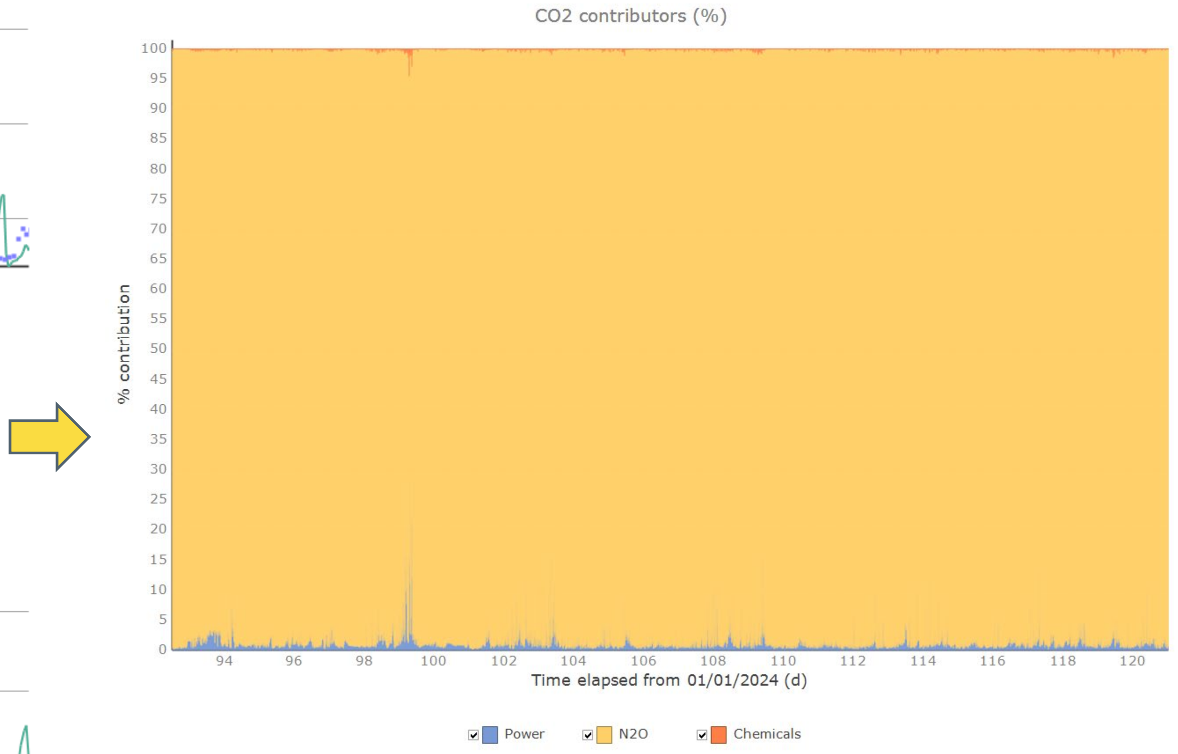
Modelled vs. Measured N2O Concentrations

Process Tank 2 – N_2O



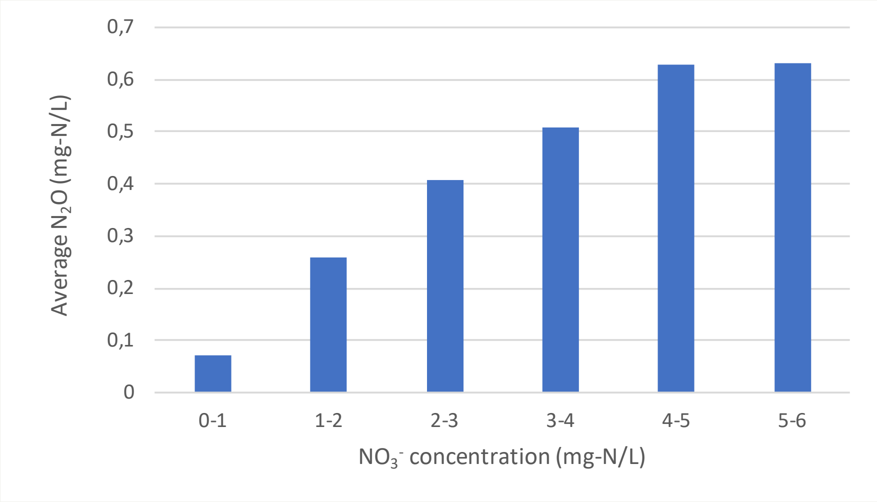
Process Tank 3 – N_2O

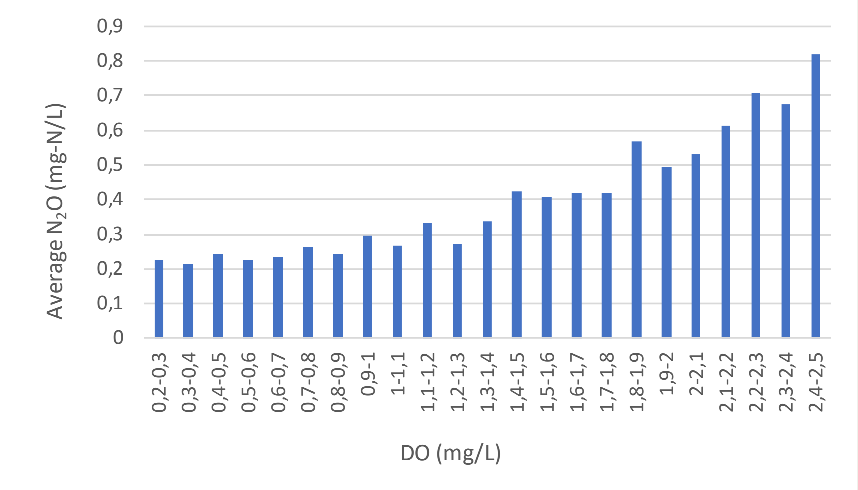


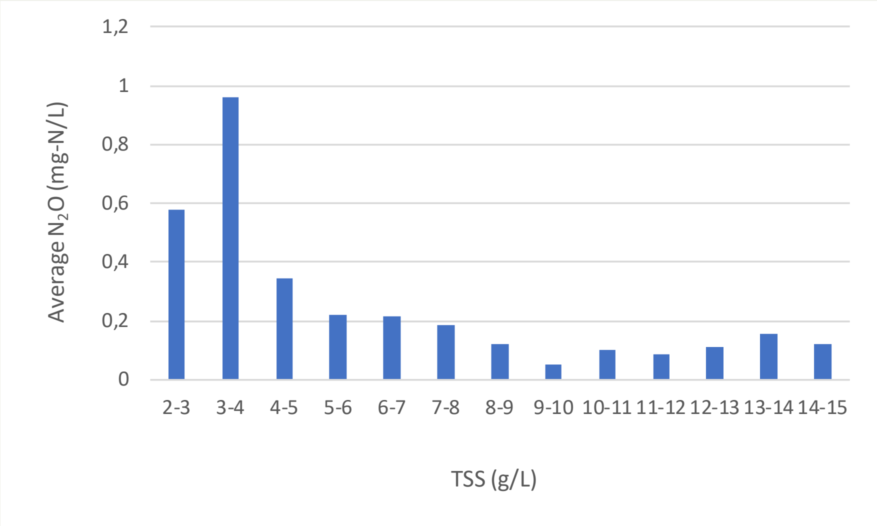


EF_{N2O} = 1.3% kg N_2O-N/kg N

Scenario Analysis (offline WEST modeling)







NH4 SETPOINTS HUBGRADE CONTROLLER				OUTPUTS					
0,5	2	4	6	CO_2 eq released (kg/d)	Cost (€/m3)	COD (mg/L)	NH4 (mg-N/L)	TN (mg-N/L)	TP (mg-P/L)
DOsp_0	DOsp_1	DOsp_2	DOsp_3						
0,2	0,2	1,0	1,0	16312,4	0,4	26,8	1,4	4,1	1,0
0,2	1,0	1,0	1,0	17444,0	0,4	26,8	1,2	4,7	1,0
1,0	1,0	1,0	1,0	17556,2	0,5	26,7	0,7	6,3	1,1
0,2	0,2	1,0	2,5	16791,6	0,4	26,8	1,3	4,1	1,0
0,2	1,0	1,0	2,5	16616,0	0,4	26,8	1,0	4,7	1,0
0,2	0,2	2,5	2,5	17029,3	0,4	26,8	1,1	4,1	1,0
0,2	1,0	2,5	2,5	18175,1	0,4	26,8	0,7	4,9	1,1
1,0	1,0	2,5	2,5	18329,2	0,5	26,7	0,5	6,5	1,2

Pairing of measured data with N_2O (liquid phase)

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Roundtable Discussions

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Q&A

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Call to Action

Felicia Marcus
William C. Landreth Visiting Fellow
Water in the West
Stanford University

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ENVIRONMENT

SOCWA
South Orange County Wastewater Authority

SYNAGRO
A Residuals Management Company

City of Richmond

Woodard & Curran

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CASA CWEA

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Attendee Happy Hour Meet-up

DAVID BROWER CENTER Terrace

2181 Shattuck Ave
Berkeley