What Monitoring Tools do we Need to Ensure the Safety of Direct Potable Reuse?

WRF 4508/WRRF 13-14

Jennifer Hooper
Channah Rock (PI)
Kati Bell (co-PI)
Shane A. Snyder (co-PI)
Allegra da Silva
Jeff Mosher

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THE UNIVERSITY OF ARIZONA

NWRI National Water Research Institute

CDM Smith

Motivation

- DPR is happening
  - Wichita Falls, Texas (15 mgd)
  - Big Spring, Texas (2.5 mgd)
  - Brownwood, Texas
  - Cloudcroft, New Mexico
  - Windhoek, Namibia (5.6 mgd)
- Regulators and water managers lack a framework to assess DPR
  - Multi-barrier approach
  - Enhanced monitoring (but of what?)

Project #	WRRF-14-19	WRRF-14-18	WRRF-14-17	WRRF-14-16	WRRF-14-15	WRRF-14-14	WRRF-14-13	WRA-14-01	WRRF-14-12	WRRF-14-10	WRRF-14-08	WRRF-14-03	WRRF-14-02	WRRF-14-01	WRF4536*	WRF4508*	WRRF-13-13	WRRF-13-12	WRRF-13-03	WRRF-13-02	WRRF-12-07	WRRF-12-06	WRRF-11-10	WRRF-11-05	WRRF-11-02	WRRF-11-01
DPR vs. alternatives, Economics									x		x	x														
Evaluation of potential DPR trains				x			x		x	x		x							x			x	x		x	x
Demonstration of reliable, redundant treatment performance	x		x	x			x		x	x				x		x			x		x	x	x	x	x	x
Critical Control Points				x					x	x									x							
Pathogens: surrogates, credits		x	x	x			x		x	x			x	x	x				x			x			x	x
Pathogens: Rapid/continuous monitoring		x	x	x						x				x								x				x
Failure and resiliency				x			x		x								x		x				x			
Public perception and acceptance																				x		x				
CEC removal and risk	x				x	x			x																x	
Operations Training, Framework				x				x									x									
Source Control																		x								

*funded and managed by Water Research Foundation

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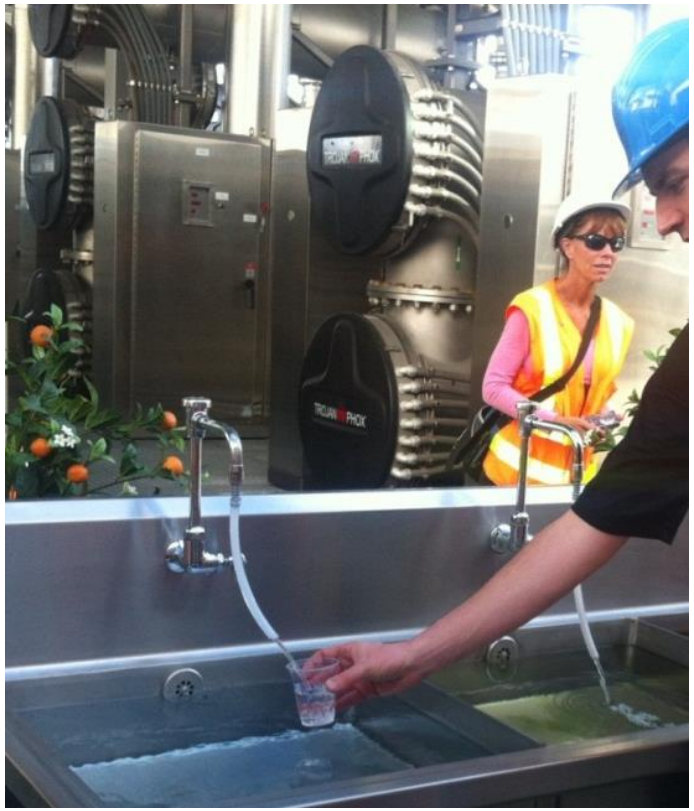
Research Approach

1. **Literature review** to identify tools to monitor DPR
2. **Two expert workshops**
   - Microbial
   - Chemical
3. **Demonstrate monitoring techniques** at multiple existing IPR/DPR facilities side-by-side
4. **Produce a practical framework** for DPR monitoring



Team

- University of Arizona
  - Channah M. Rock (PI)
  - Shane A. Snyder (co-PI)
- CDM Smith
  - Kati Bell (co-PI)
  - Allegra da Silva
  - Jennifer Hooper
- NWRI
  - Jeff Mosher

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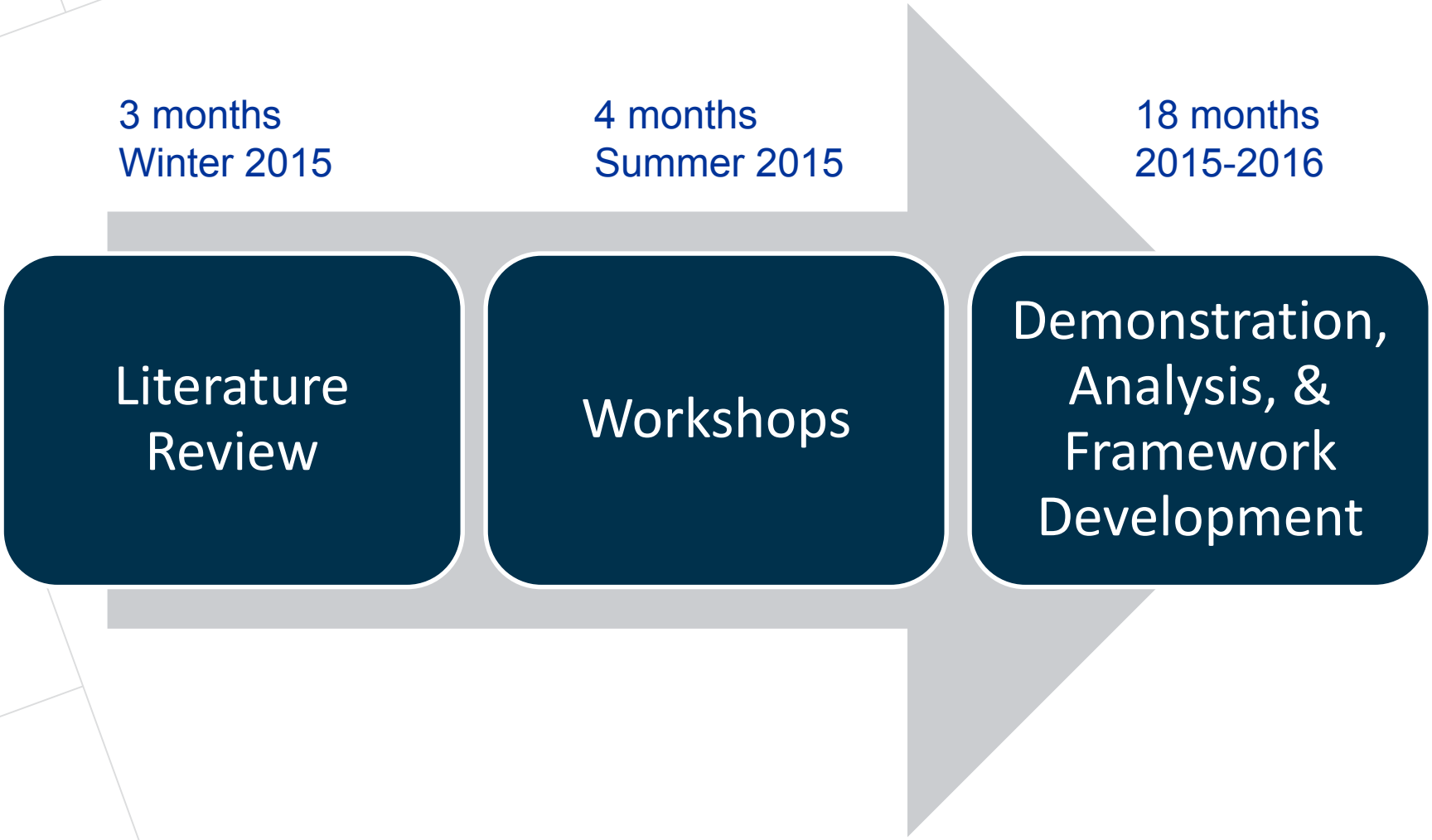
Timeline


3 months
Winter 2015
4 months
Summer 2015
18 months
2015-2016
Literature Review
Workshops
Demonstration, Analysis, & Framework Development

Task 1: Literature Review – Identify Monitoring Tools

- Microbial Assays
- Chemical Assays
- Conventional Parameters

Task 1: Literature Review

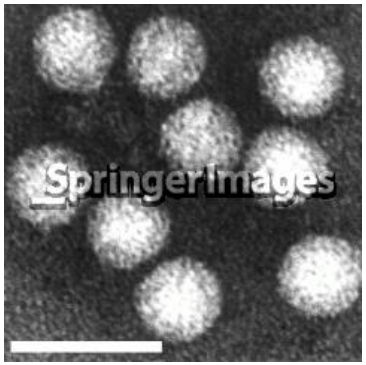
Microbial Assays

- Cell Culture
- Biological Molecules
- Molecular Biological
- Immunological
- Biosensors
- Light scattering

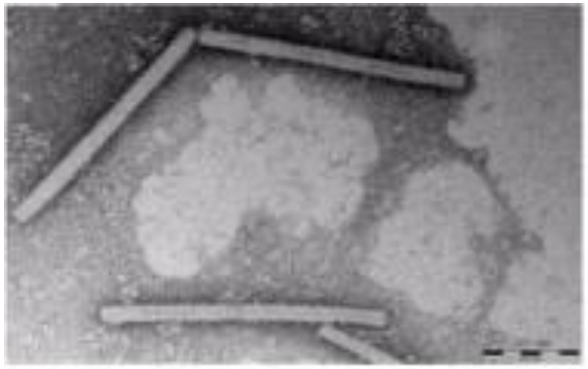
QCM (Qsense)

Viral indicators and surrogates

- Bacteriophages
- Pathogens (e.g. Adeno, Noro)
  - WRRF 14-17 “White Paper on the Application of Molecular Methods for Pathogens for Potable Reuse”
- Aichi, Calici, and Pepper Mild Mottle Virus (PMMoV)
  - Abundant in wastewater; limited seasonality
  - Not effectively removed in WWTP



Aichi virus *(Springer Images)*



PPMoV virus isolated from chilli sauce *(Colson et al, 2010)*

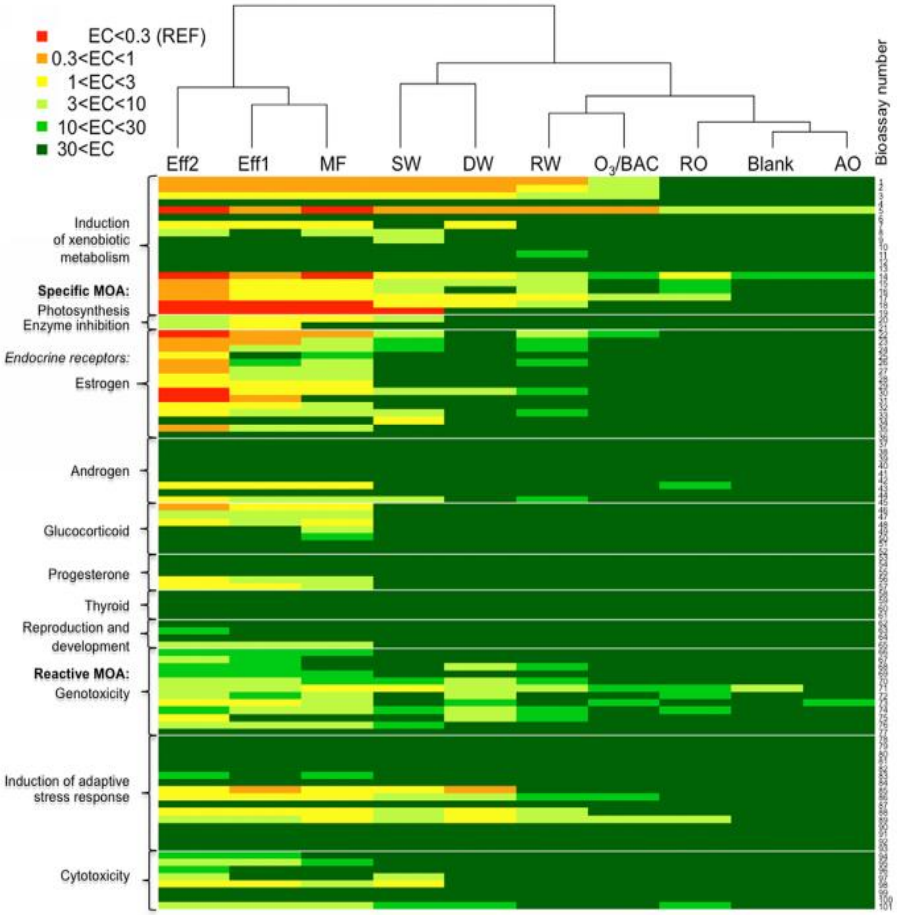
Task 1: Literature Review

Chemical Assays

- Trace Chemical Constituents
  - EDCs
  - PPCPs
  - Perfluorinated
- Bulk assays
  - Bioassays
  - EEM

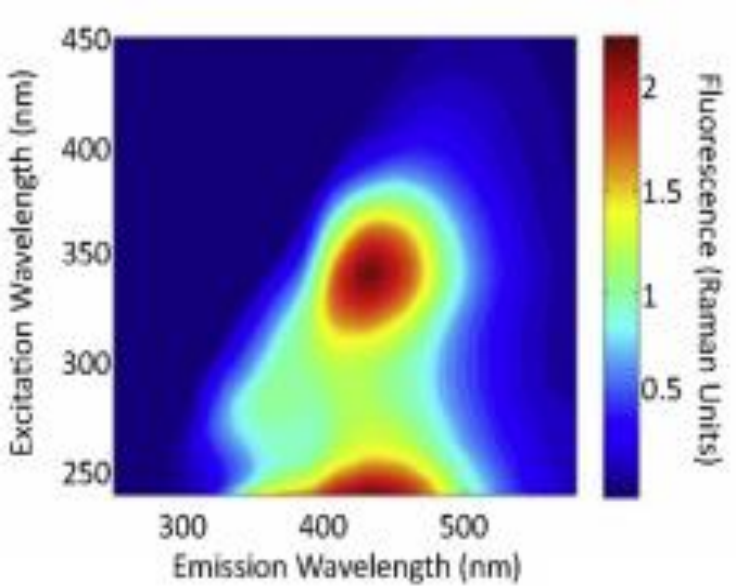
Bioassays

- Testing for individual chemicals
  - Slow
  - Doesn't capture new contaminants or degradation products
  - Lack of consensus on targets
- High throughput screening (HTS)
  - Examines cellular response
    - Mutagenicity, genotoxicity, endocrine disruption, etc.
  - Captures mixture effects
  - 100's - 1,000's of types of assays
    - Whole effluent toxicity (WET) testing for WWTPs



Escher et al. (2013) *ES&T*

Fluorescence Excitation/Emission Matrix (EEM)



Task 1: Literature Review

Conventional Parameters

- Organic Carbon
  - TOC/DOC
  - Carboxylic acids
  - Fluorescence
  - Ultraviolet/Visible (UV/Vis) Spectroscopy
- Conductivity
- Total Nitrogen
- Turbidity
- Temperature
- pH

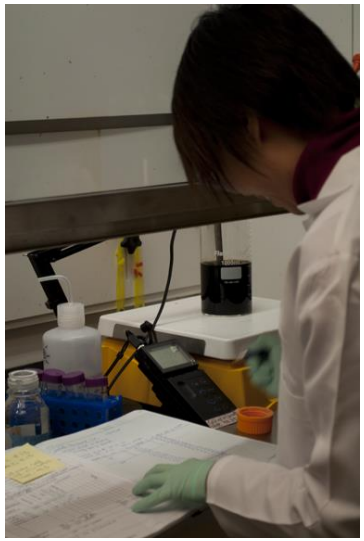
Summary of recommended methods

Microbial	Chemical	Conventional
Fecal coliform *E. coli* Enterococci	~20 targeted EDCs, PPCPs, and perfluorinated compounds (GC/MS and LC/MS)	Conductivity
G. lamblia *C. parvum* *C. perfringens*	Bioassays	Turbidity
Bacteriophage Viral pathogens	Fluorescence EEM	TOC
ATP		UVA; UV/Vis
Aichi, Calici, PMMoV?		Total nitrogen

Plus alternative methods selected by workshop participants

Task 2: Expert Workshops

- Information from existing
  - IPR/DPR facilities
  - research projects
  - epidemiology and toxicology studies
- Goals are to recommend
  - 1) a targeted suite of analytical methods for **microbiologic** and **chemical** COCs
  - 2) potential uses of bioassays for DPR
  - 3) develop initial set of safety criteria
  - 4) applicability of IPR epidemiological studies for DPR and needs for epidemiological and/or health surveillance studies
- Develop suite of analyses for full-scale testing



Task 3a: Demonstrate Techniques at Existing IPR/DPR Treatment Systems

Level	Commitment	Participation
1	Share treatment train & operational data	Open to all utilities
2	**Quarterly sampling** through **multiple stages** of treatment for **one full year**	Selection by technical advisory group to represent varying geography, baseline conditions, and treatment trains
3	Same as Level 2	Open to non-selected utilities that can support the additional analytical cost

Preliminary List of Collaborators

Utility	Location	Classification
Upper Occoquan Service Authority	Virginia, US	IPR
Gwinnett County Department of Water Resources	Georgia, US	IPR
Clayton County Water Authority	Georgia, US	IPR and wetlands
Denver Water	Denver, CO	IPR
Orange County Water District	Fountain Valley, CA	IPR
City of Scottsdale	Scottsdale, AZ	IPR
West Basin Municipal Water District	El Segundo, CA	IPR and NPR
Public Utilities Board	Singapore	IPR and NPR
Water Replenishment District of So. CA	Long Beach, CA	ASR
Greater Cincinnati Water Works	Cincinnati, OH	IPR
Village of Cloudcroft	Cloudcroft, NM	DPR
City of Wichita Falls	Wichita Falls, TX	IPR and DPR
Colorado River Municipal Water District	Big Spring, TX	DPR

Task 3b: Analyze results & create framework

Microbial Assays

- Cell Culture
- Biological Molecules
- Molecular Biological
- Immunological
- Biosensors

Chemical Assays

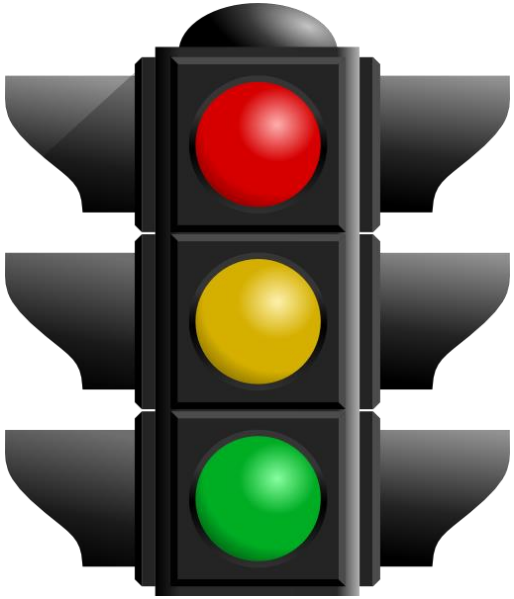
- Trace Chemical Constituents
  - EDCs
  - PPCPs
  - Perfluorinated
- Bioassays
  - Nuclear xenobiotic receptors
  - Geno or chemical tox indicators

Conventional Parameters

- Organic Carbon
  - TOC/DOC
  - Carboxylic acids
  - Fluorescence
  - Ultraviolet/Visible (UV/Vis) Spectroscopy
- Conductivity
- Total Nitrogen
- Turbidity
- Temperature
- pH

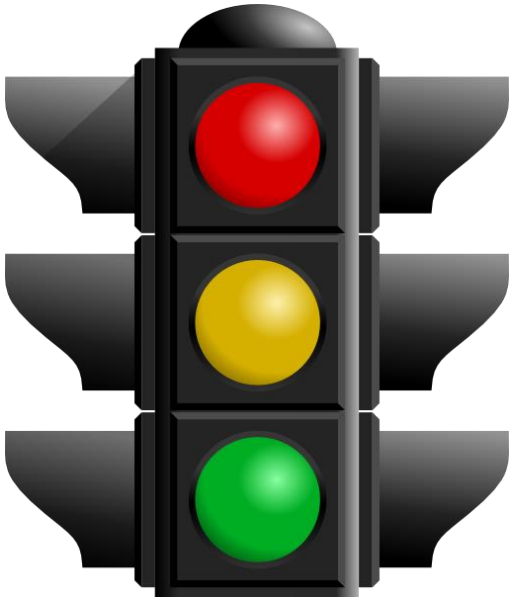
Evaluating Analytical Methods

- Usefulness
- Implementability
- Data Quality, Reliability
- Cost



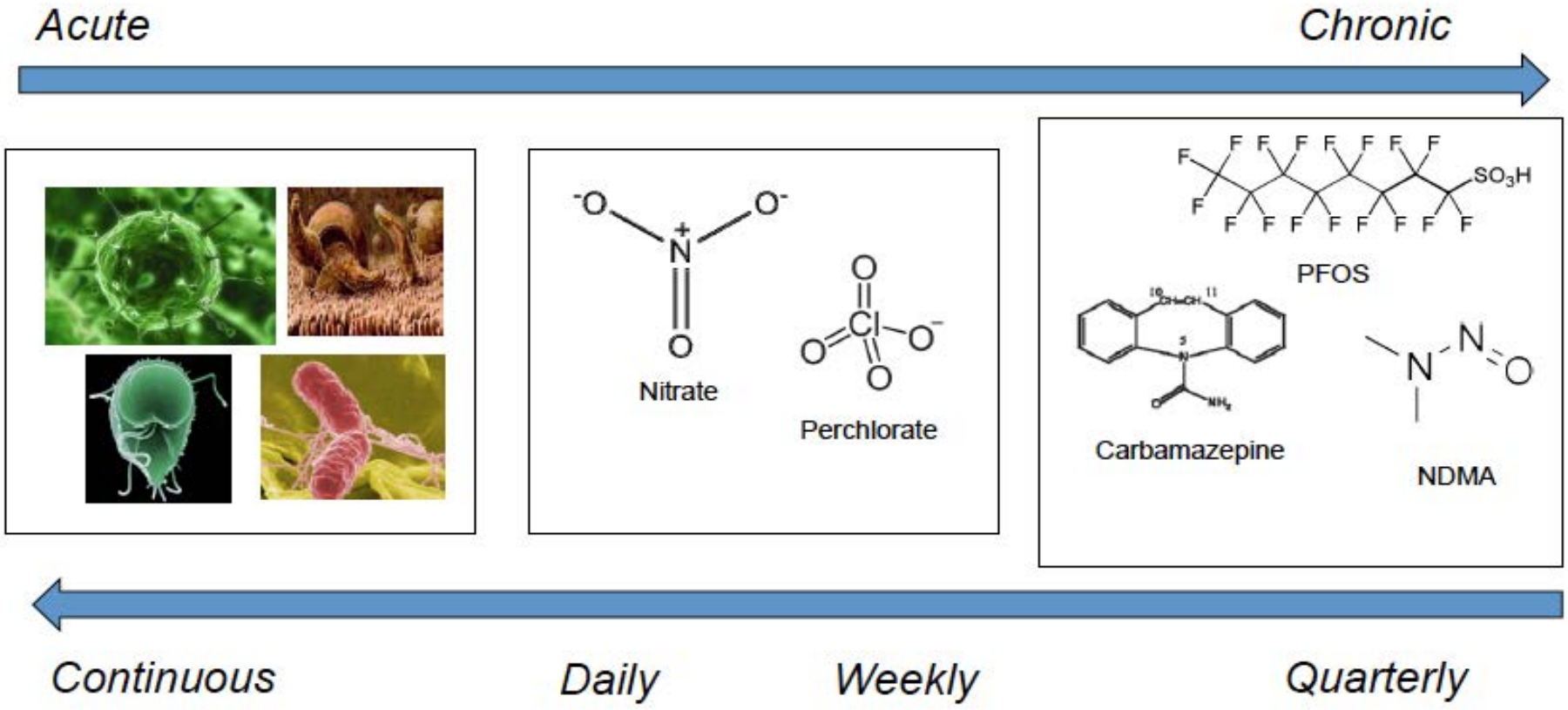
Task 3b: Develop DPR monitoring framework

Analytical method	Unit process 1	Unit process 2	Unit process 3	Unit process 4
A				
B				
C				
D				
… etc.	?	?	?	?



General Monitoring Strategy

- The more acute the threat, the more strictly it must be monitored and controlled
- Response Retention Time (treatment and failure response)



Method Evaluation

Conventional Parameters – Organic Carbon

Total organic carbon (TOC)

Criterion		Rating	Explanation
Usefulness	Metrics for evaluation	3	Ranges in values
	Correlations to treatment objectives	5	Directly related to
	Ability to control	5	demonstrated abil
	Response/turnaround time	2	Requires a few ho
Data Quality	Precision	5	compares favorab
	Accuracy	5	compares favorab
	Span	4	compares favorab
	Representativeness	4	Fairly well accepte
	Selectivity/specificity	5	Highly specific ana
Implementability	Technology maturity	3	Developed from s
	Training requirements	2	Requires specializ
	Ease of use	2	Difficult for person
	Data acquisition requirements	1	Requires manual
	Applicability to small utilities	2	More likely to be u
Cost	Capital	1	Purchase of lumin
	Operating and maintenance	2	Low costs for cons
Recommendations	*This method has a significantly shorter analysis time and is less cumb evaluation.*		

Key: 1 = very unfavorable/very high cost 2 = unfavorable/high cost 3 = average 4 = fa

- Ratings by category
- Recommendations
- Method Description
- Applicable Treatment Objectives
- Typical ranges
- Interferences
- Implementation Requirements
- Cost
- References

Expected Outcomes

- Framework will aid in treatment process selection, process validation and monitoring.

- Intended to address utility, public, and regulatory **concerns about DPR safety**.

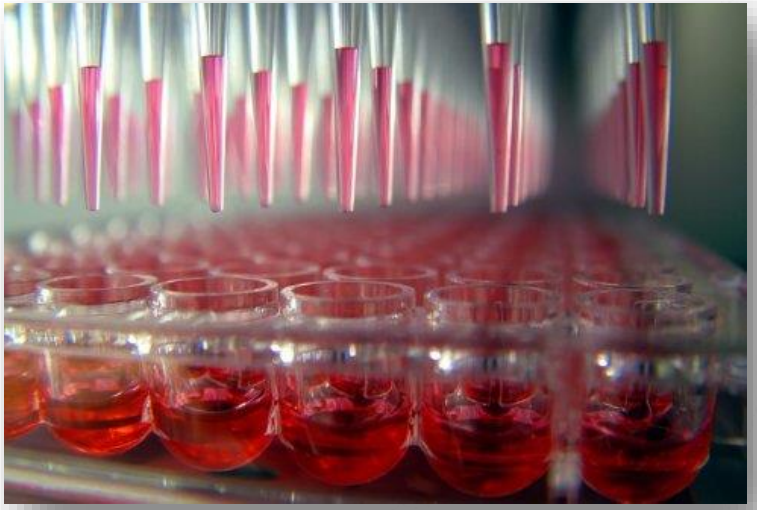
Monitoring Framework

Future Monitoring Research Needs

- Human health relevance of Bioassays
- Pathogen monitoring
- Operator friendliness is key - are operators able to handle complex processes?
- How do we use monitoring tools to answer questions in a more holistic way?
- Cast the biggest net possible,

  yet remain efficient.
- Method variability
- Data interpretation /

  Standardized SOPs



QUESTIONS?

Jen Hooper – HooperJL@cdmsmith.com