Reliability and Robustness for CEC Control in Potable Reuse

Brian Pecson, Ph.D., P.E.

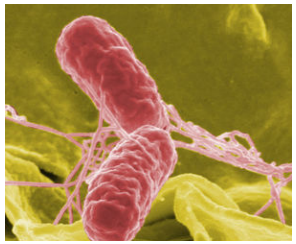
State Board CEC Workshop
October 28, 2015

Trussell TECHNOLOGIES INC

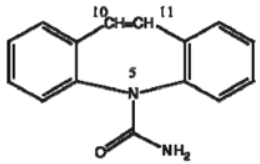
Public Health Protection

DPR must not harm public health!!!

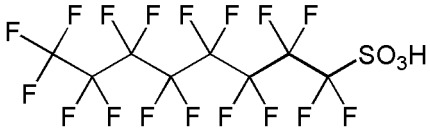
Pathogens



Toxic Chemicals



Carbamazepine



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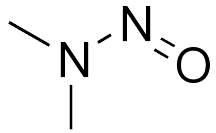
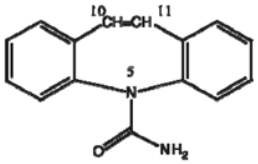


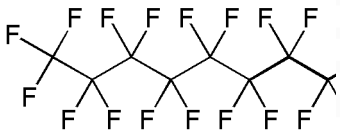
NDMA

Types of Threats

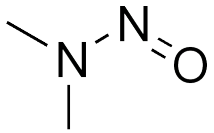
Toxic Chemicals



Carbamazepine

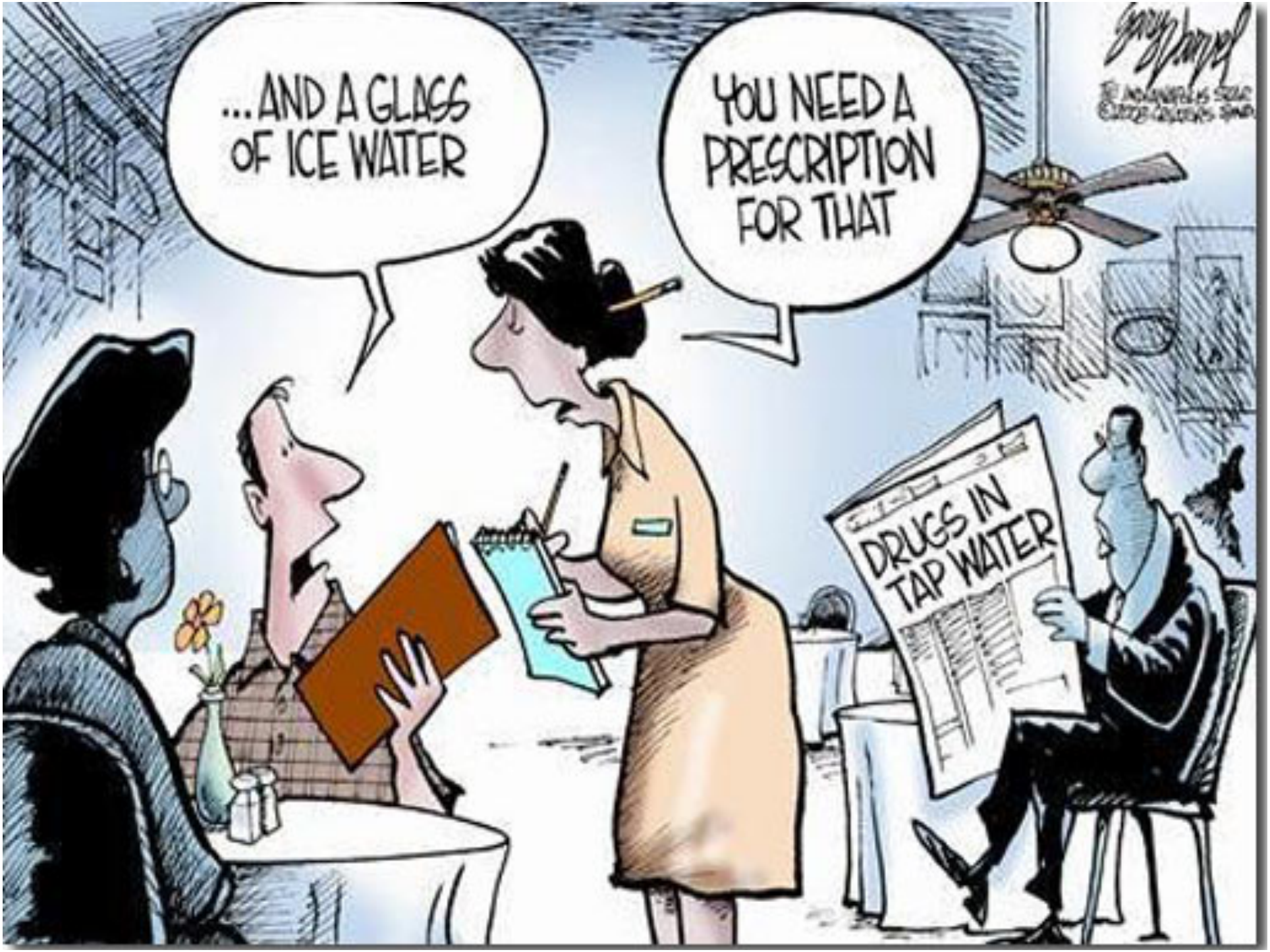


PFOS



NDMA

Pathogens


...AND A GLASS OF ICE WATER
YOU NEED A PRESCRIPTION FOR THAT
DRUGS IN TAP WATER


Rx Directions:
FILL THIS CONTAINER WITH TAP WATER; DRINK TWICE DAILY
PHARMACEUTICALS FOUND IN NATIONS TAP WATER
DRUGS, MEDICATIONS

Pathogens and Potable Reuse

- Pathogen control the most critical aspect of direct potable reuse
- Why is this the case?
  - Pathogens → immediate effect
  - Chemicals → long-term effect

Pathogens and Potable Reuse

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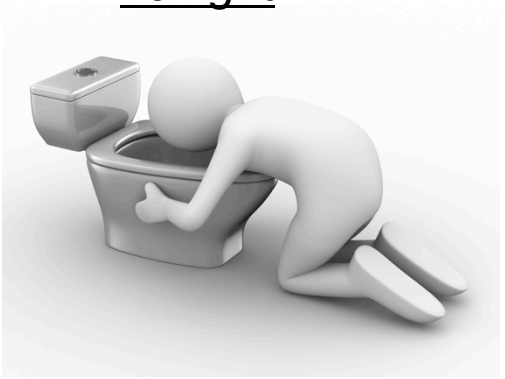
Constant threat requires constant protection

  - Chemicals → long-term effect

Tonight



Pathogens and Potable Reuse

- Pathogen control the most critical aspect of direct potable reuse
- Why is this the case?
  - Pathogens → immediate effect

Constant threat requires constant protection

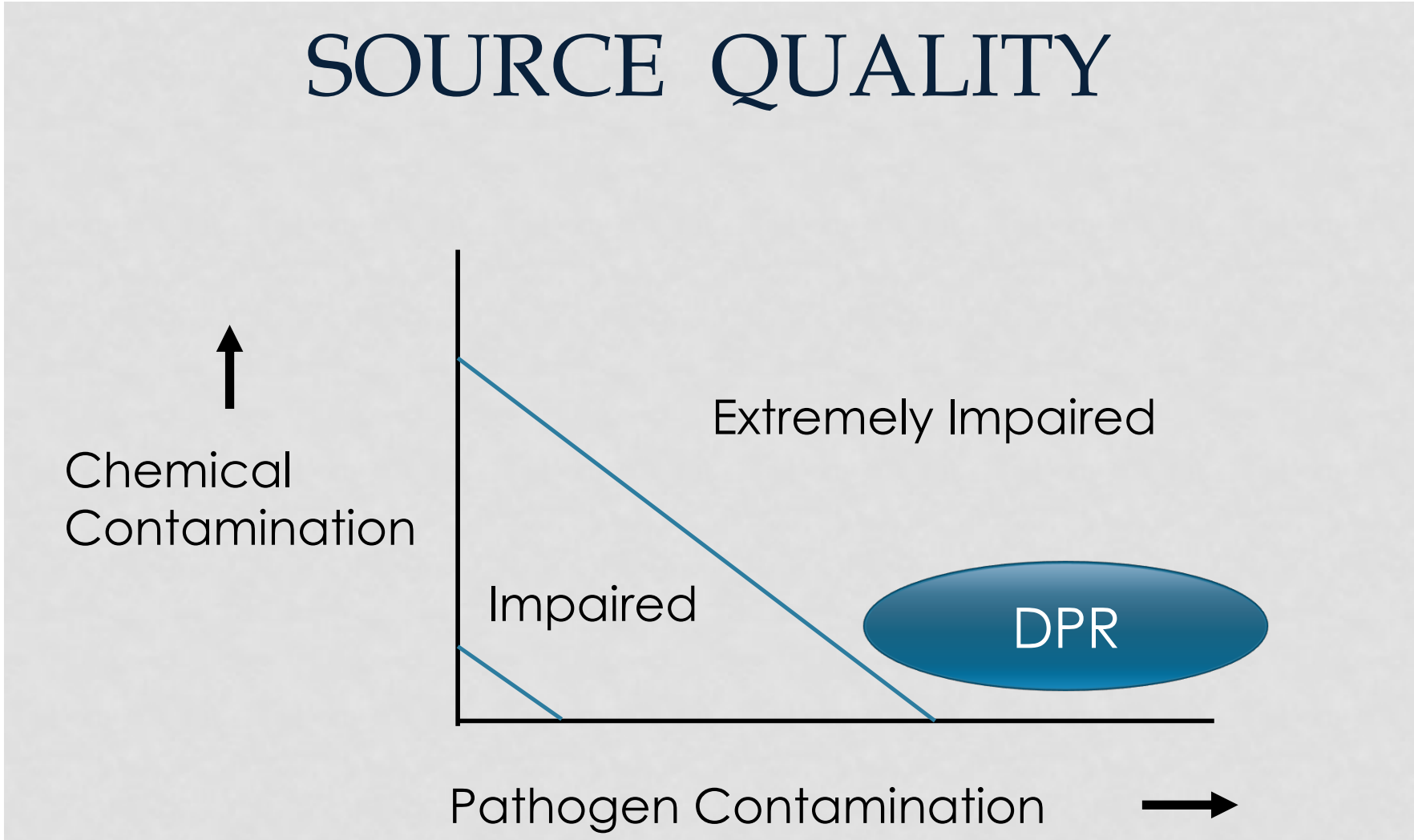
Tonight

  - Chemicals → long-term effect

Brief exceedances less important than avg. lifetime exposure

Lifetime

DDW Perspective on Risks



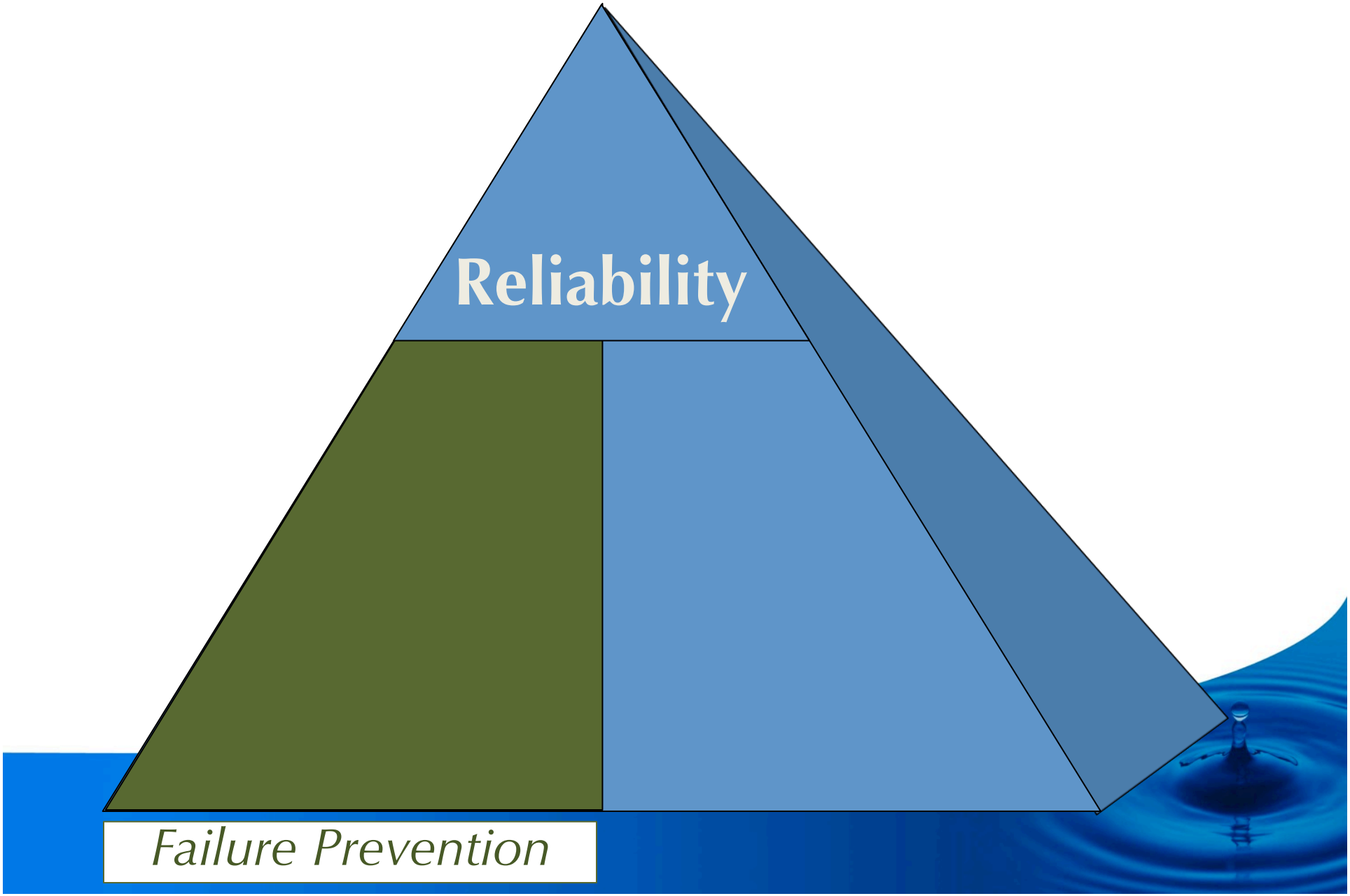
Courtesy of Bob Hultquist (DDW consultant)

A Closer Look…at Chemicals

- Industry tends to focus on chemicals
- Modern analytical equipment is amazing!!!
- A number of questions arise:
  - If we can detect it, does it mean it's dangerous?
  - What should we look for? What levels are safe?
- Numerous groups of experts help out
  - NWRI Expert Panel for WateReuse 11-02
  - Define set of chemical criteria to protect public health

Public Health Criteria for DPR

- WRRF 11-02: Includes pathogen and toxic chemical criteria (including CECs)


Reliability
Failure Prevention

RELIABILITY

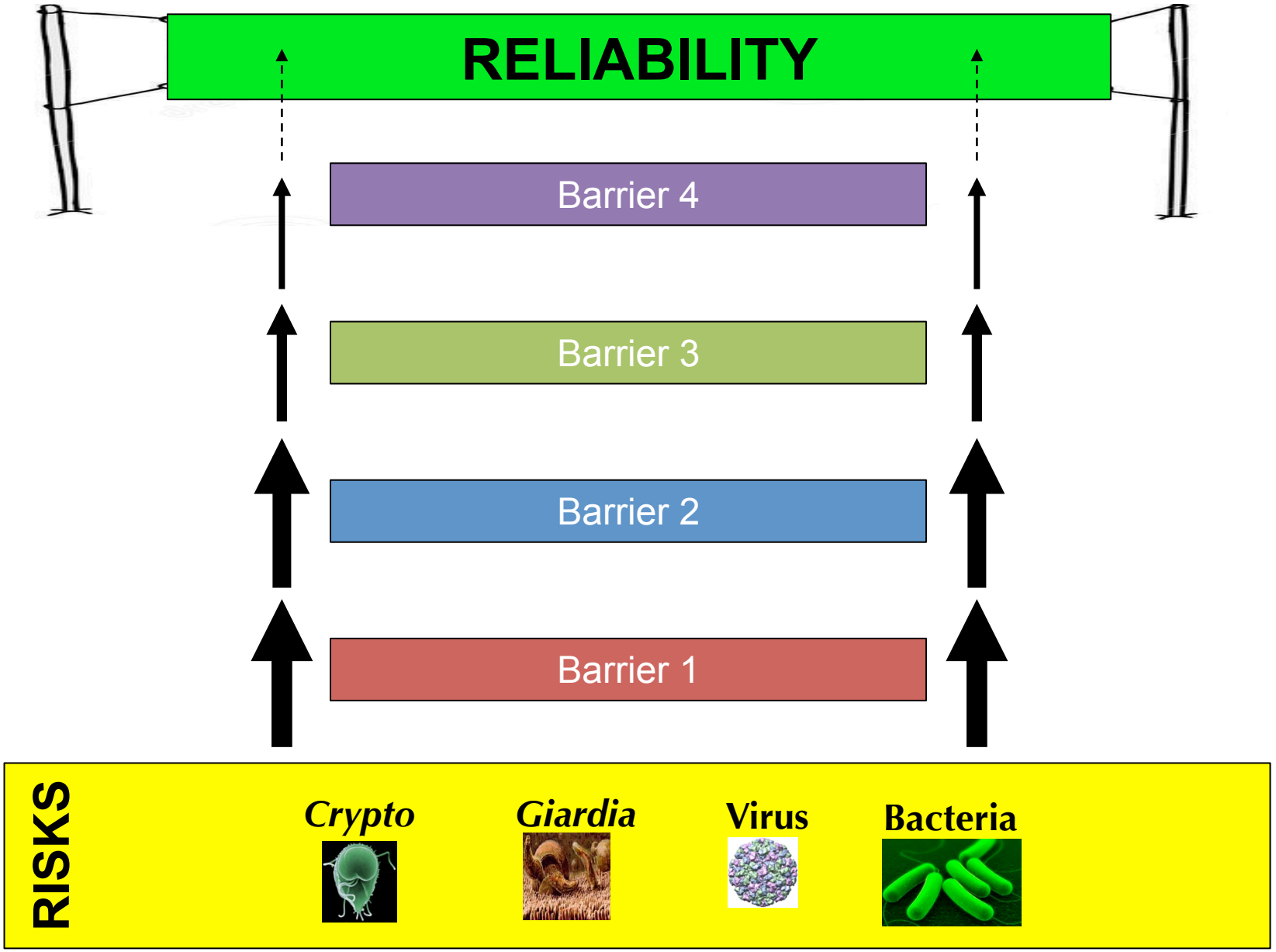
RISKS

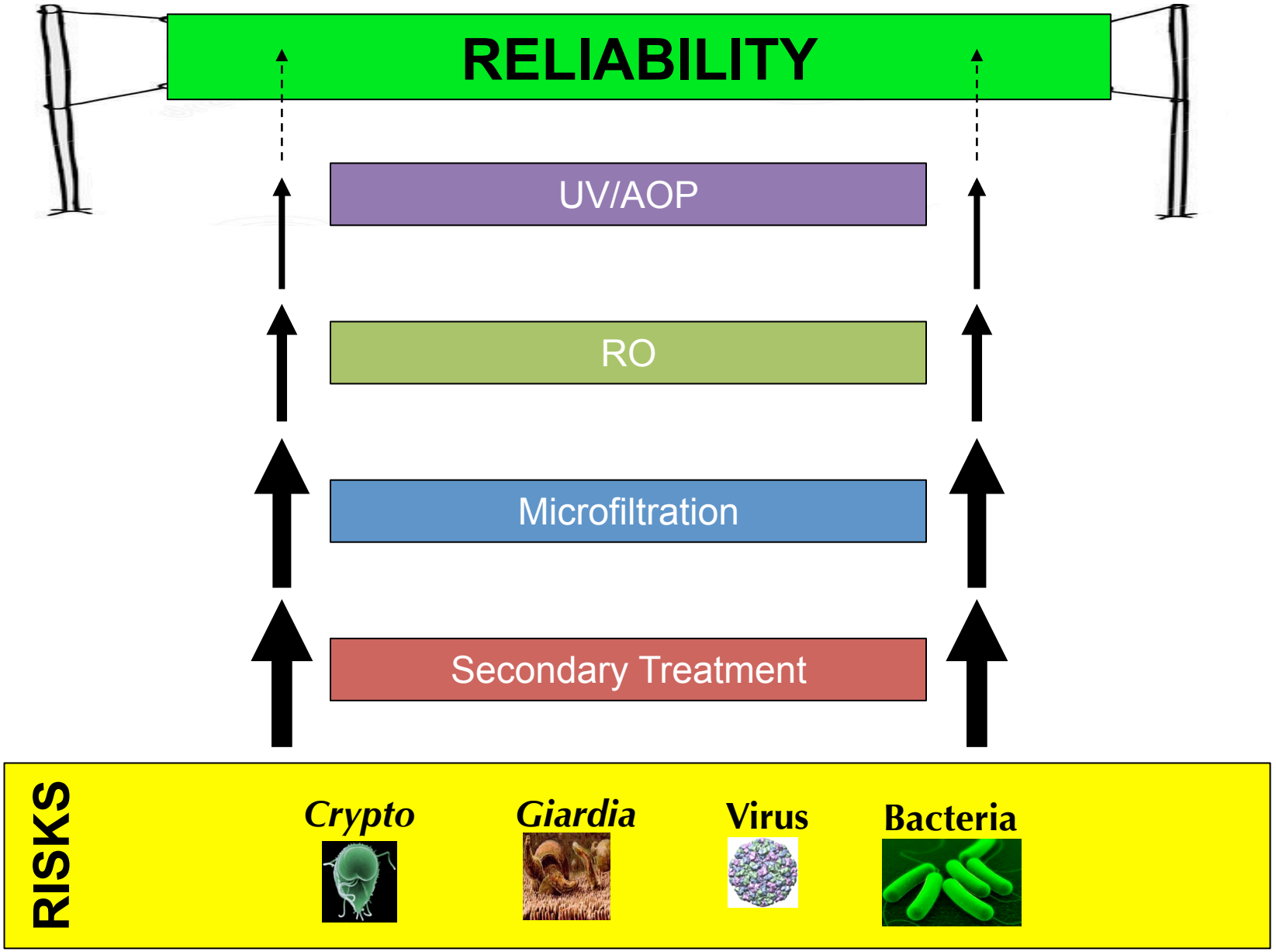
Crypto

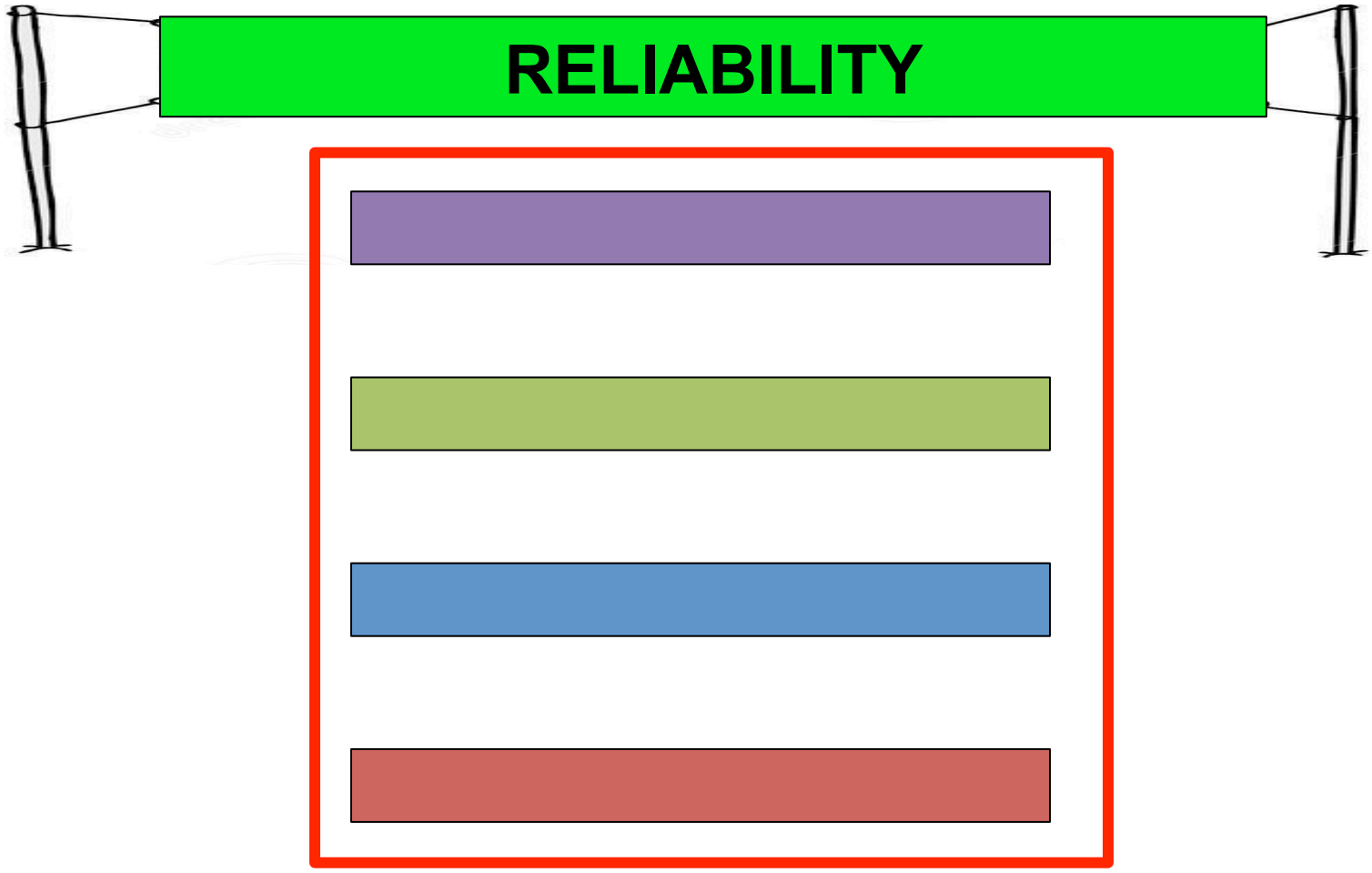
Giardia

Virus

Bacteria

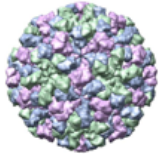

RELIABILITY
Barrier 4
Barrier 3
Barrier 2
Barrier 1
RISKS
Crypto
Giardia
Virus
Bacteria


RELIABILITY
UV/AOP
RO
Microfiltration
Secondary Treatment
RISKS
Crypto
Giardia
Virus
Bacteria

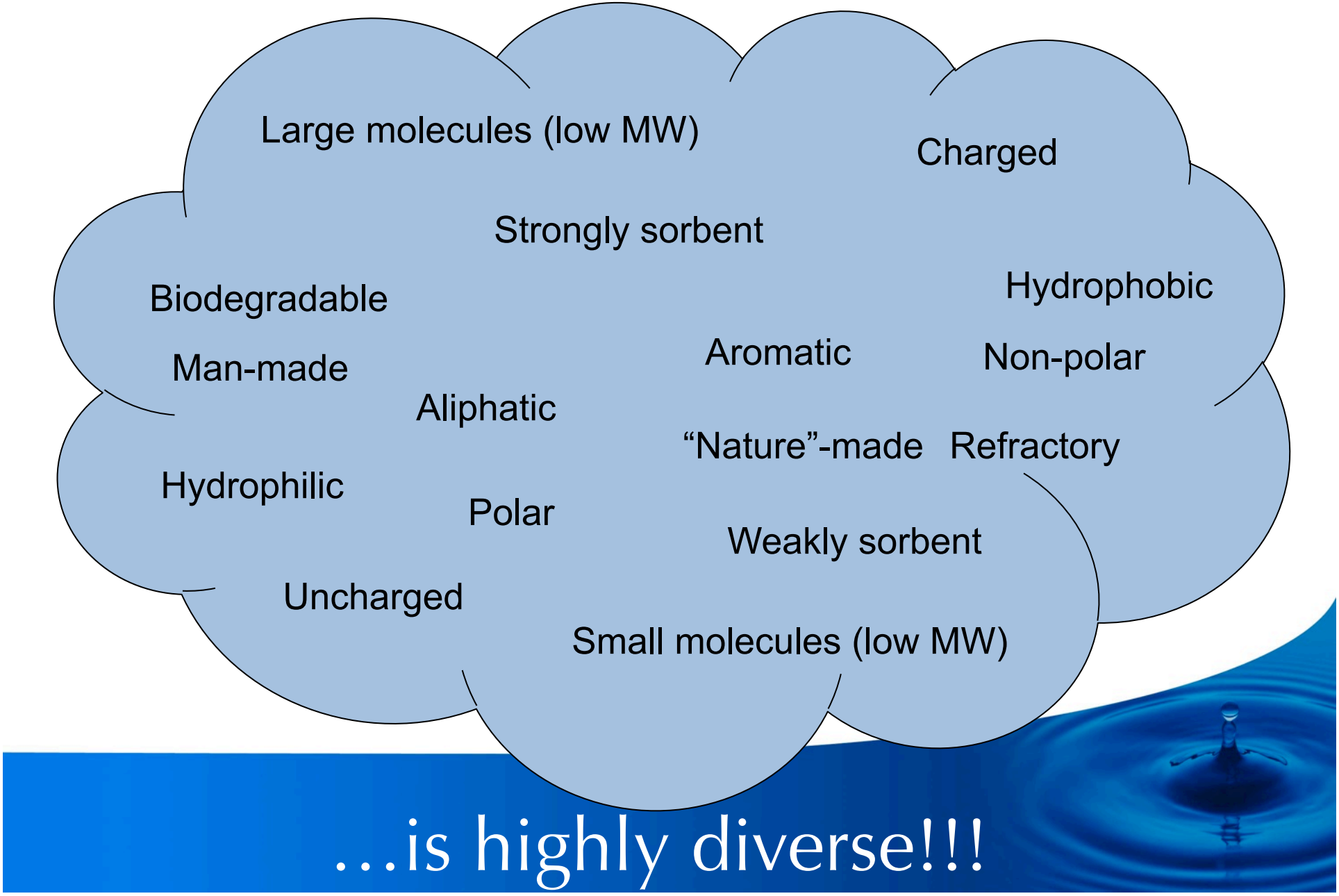


This *depth* of treatment is called REDUNDANCY

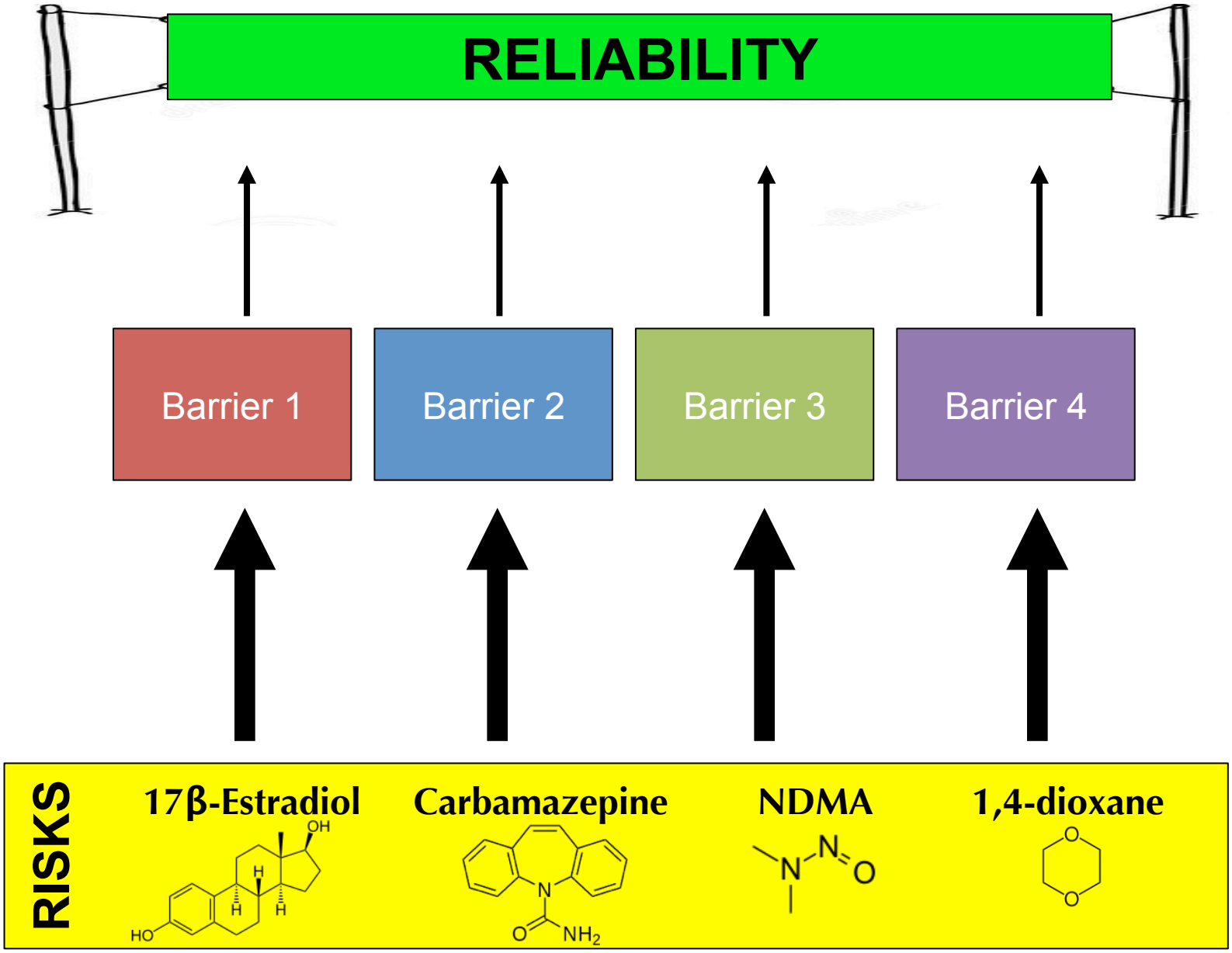


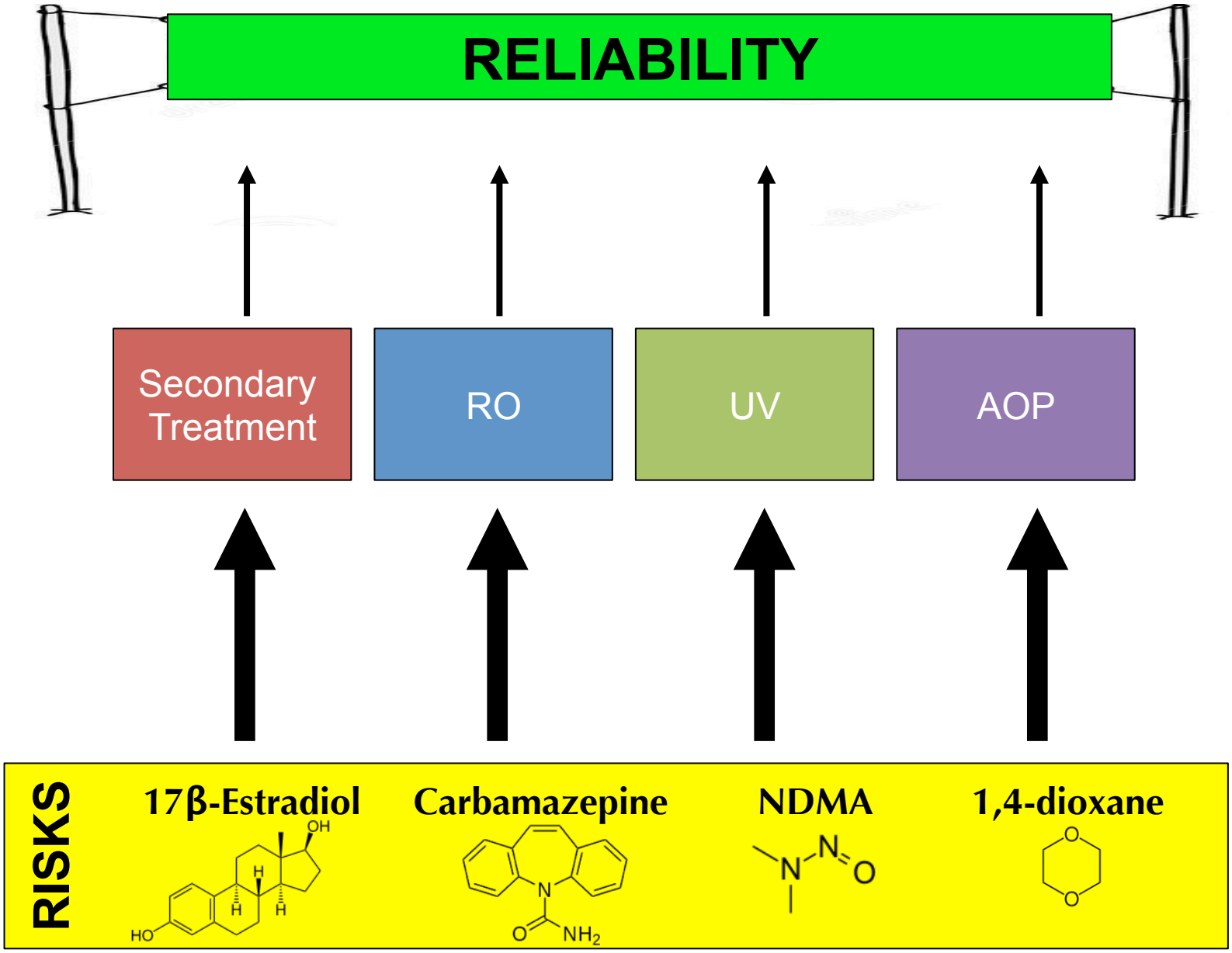



The Chemical Universe…



…is highly diverse!!!


RELIABILITY
Barrier 1
Barrier 2
Barrier 3
Barrier 4
RISKS
17β-Estradiol
Carbamazepine
NDMA
1,4-dioxane


RELIABILITY
Secondary Treatment
RO
UV
AOP
RISKS
17β-Estradiol
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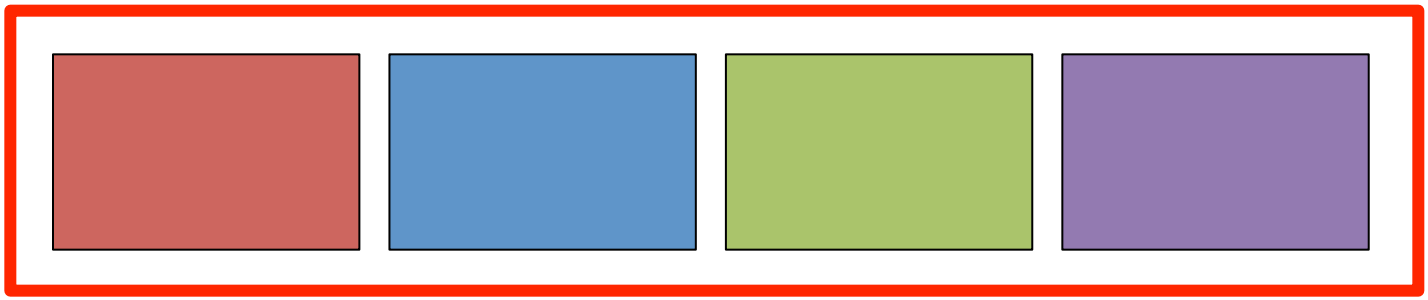
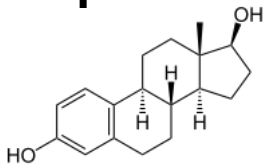
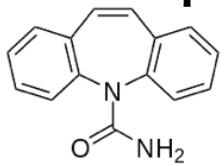


This *breadth* of treatment is called ROBUSTNESS

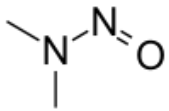
17β-Estradiol



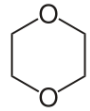
Carbamazepine



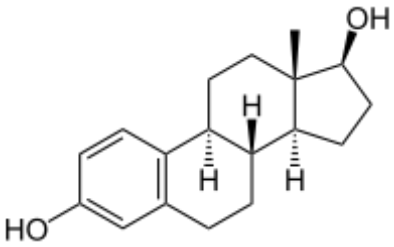
NDMA

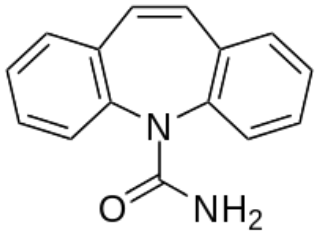


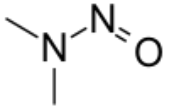
1,4-dioxane

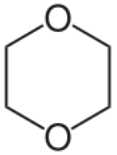


Is robustness needed?



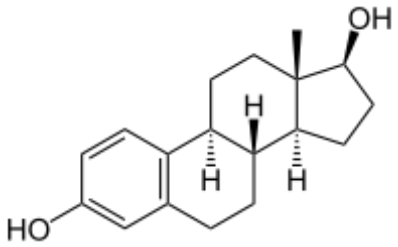


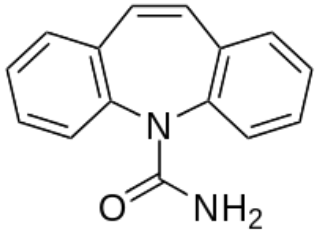


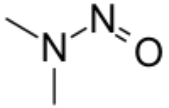


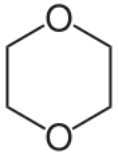
Compound	Cl_2	Biological	MF	GAC	O_3	$OH^{\cdot}$/AOP	UV	RO
17β-estradiol	Excellent	Excellent	Poor	Excellent	Excellent	Excellent	Poor	Excellent
Carbamazepine	Poor	Poor	Poor	Good	Excellent	Excellent	Poor	Excellent
NDMA	Poor	Fair	Poor	Poor	Poor	Poor	Good	Fair
1,4-dioxane	Poor	Poor	Poor	Poor	Fair	Good	Poor	Fair

Is robustness needed?









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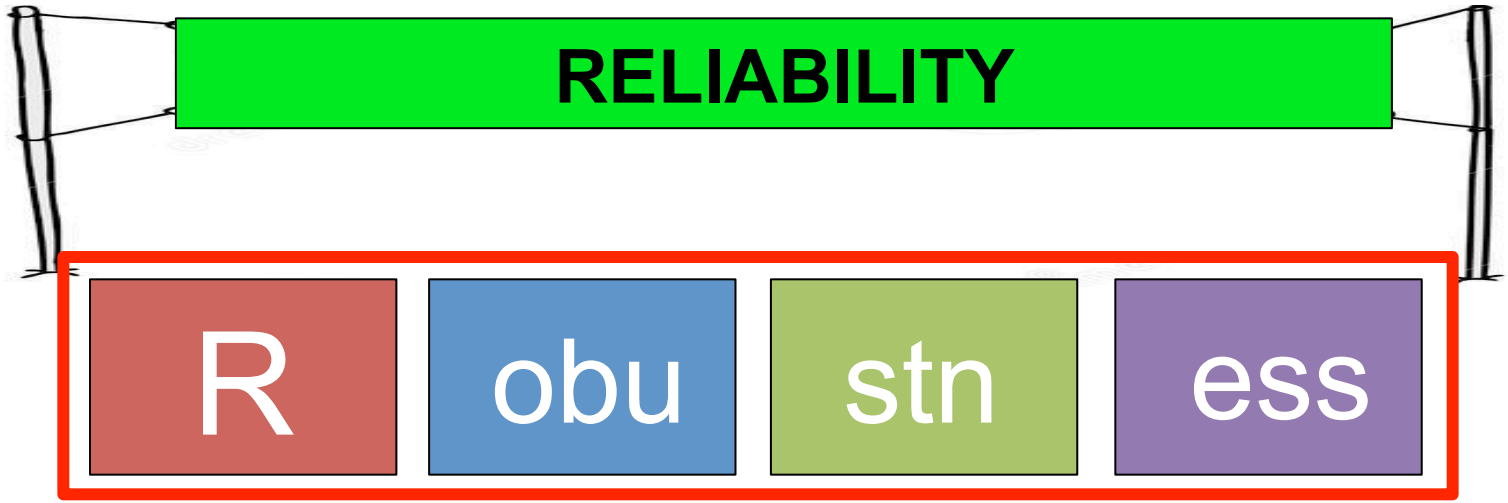
Carbamazepine	Poor	Poor	Poor	Good	Excellent	Excellent	Poor	Excellent
NDMA	Poor	Fair	Poor	Poor	Poor	Poor	Good	Fair
1,4-dioxane	Poor	Poor	Poor	Poor	Fair	Good	Poor	Fair

YES!!!

Biological Degradation | Physical Removal | Physical Destruction | Chemical Destruction

Robustness provides excellent chemical protection


RELIABILITY
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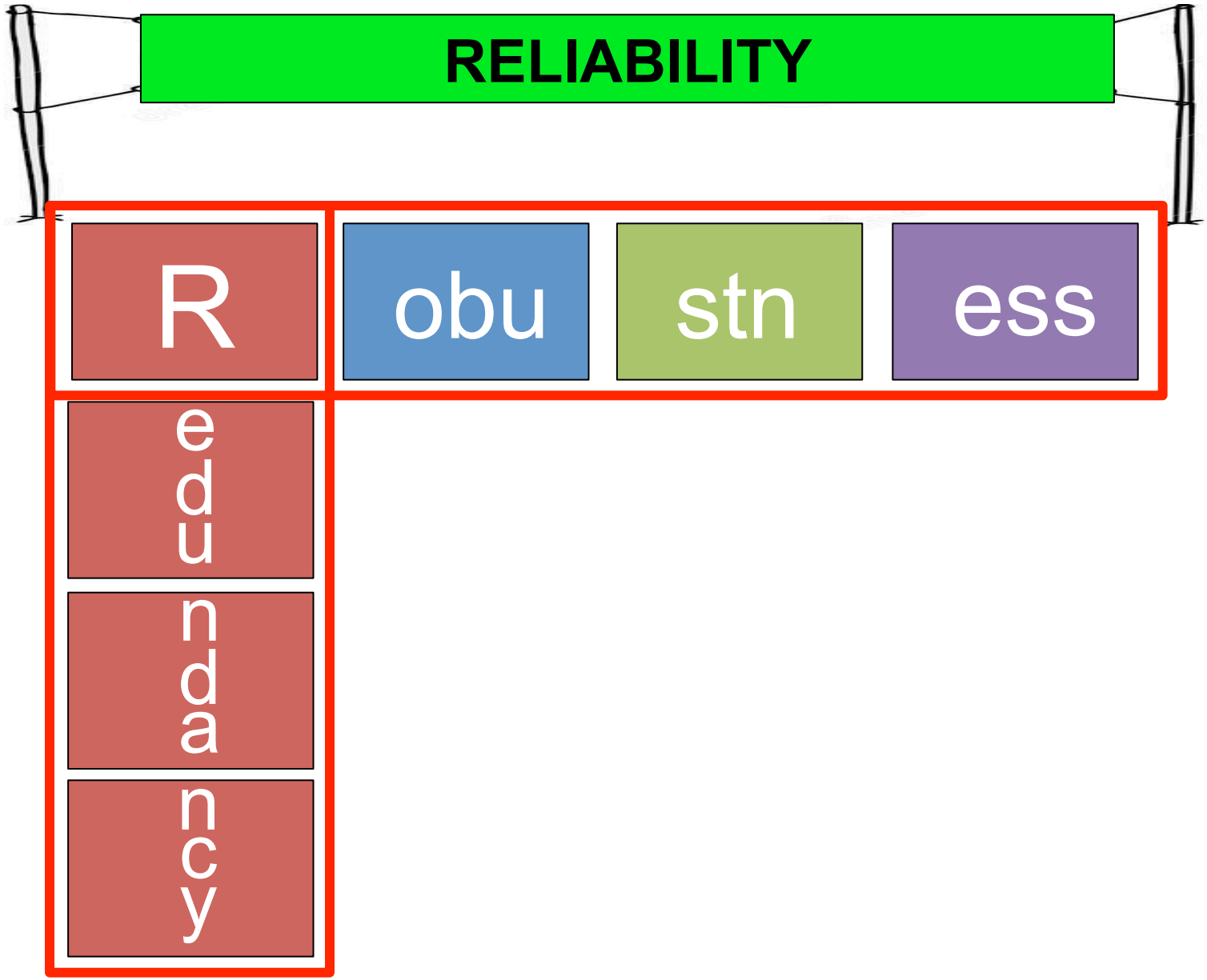
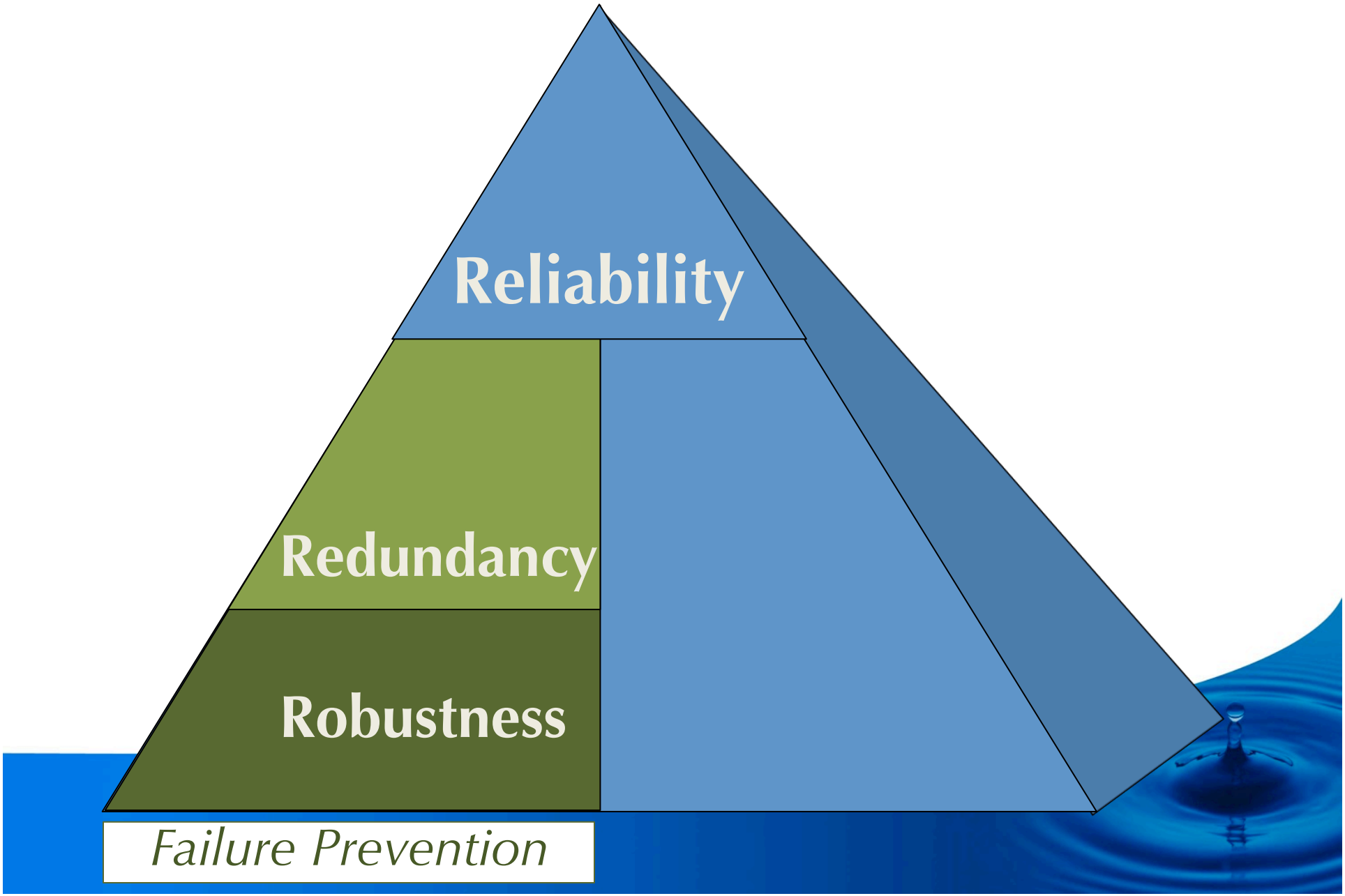
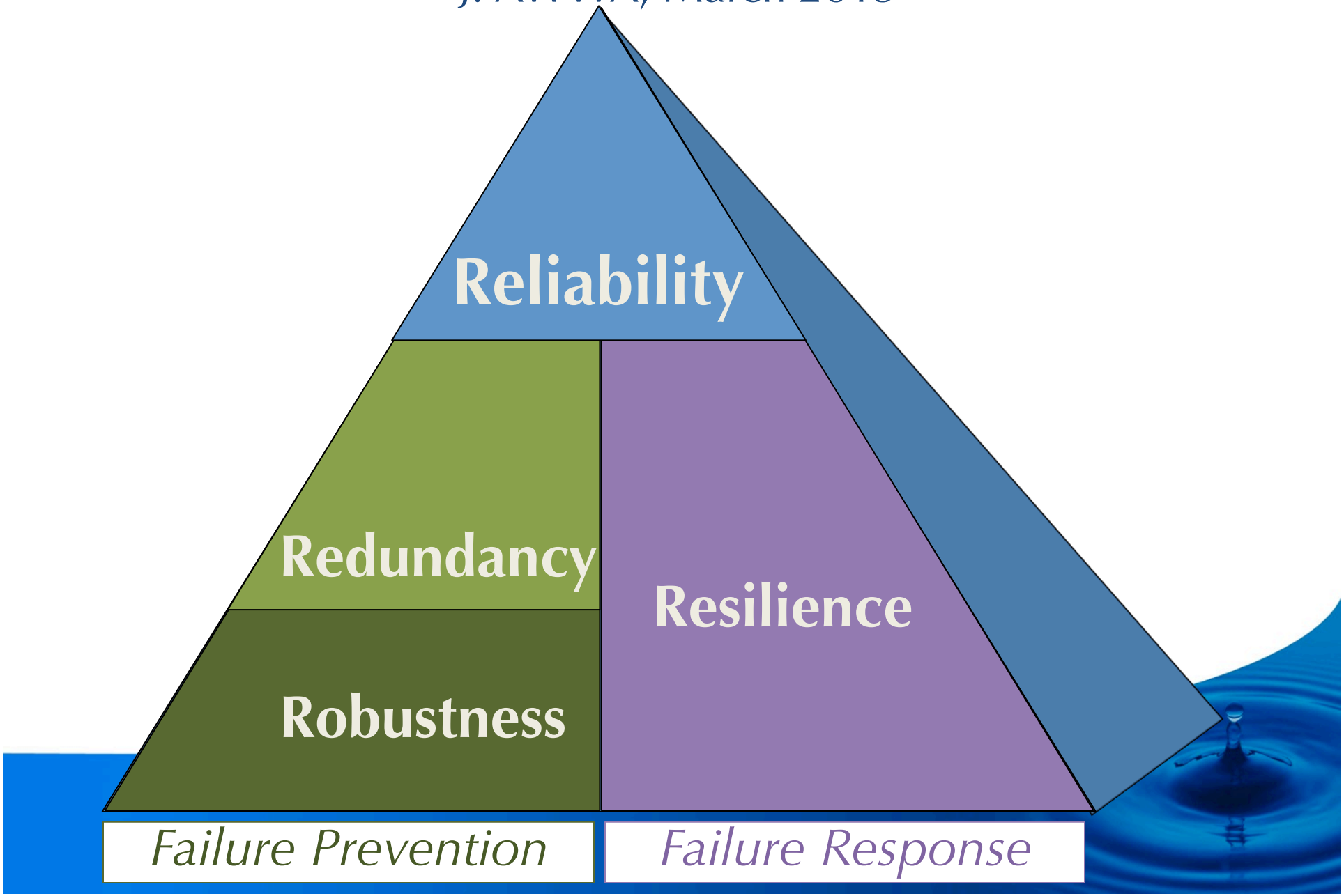

RELIABILITY
R
obu
stn
ess
redundancy


Reliability
Redundancy
Robustness
Failure Prevention

Pecson et al. "Achieving Reliability in Potable Reuse: the Four Rs" – J. AWWA, March 2015



HISTORICAL LOOK AT CECS IN POTABLE REUSE

Montebello Forebay

Montebello Forebay

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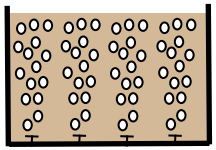
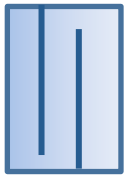


- Biological
- Adsorption
- Physical removal

3ry

- Physical removal

Chlorine

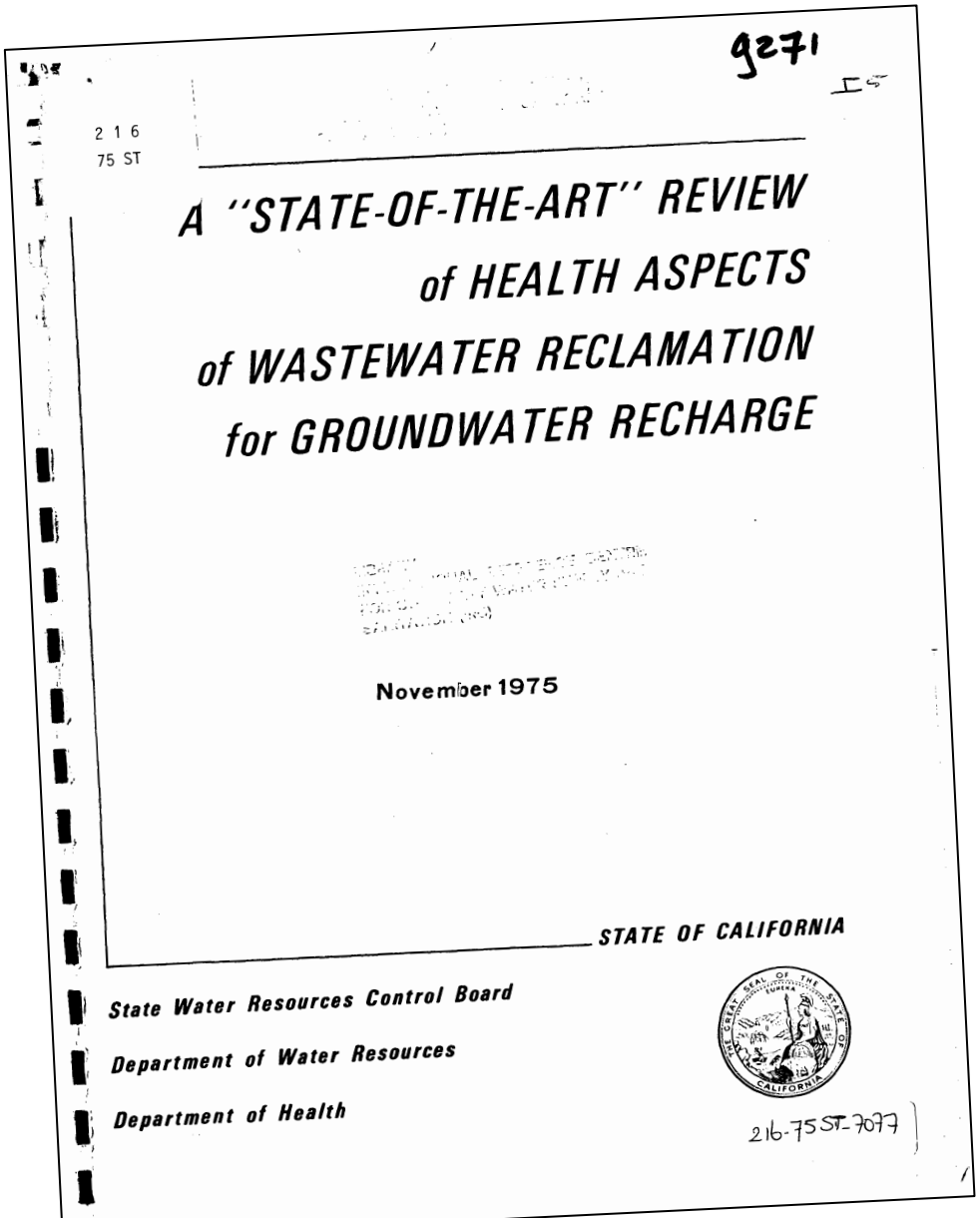


- Oxidation
- Chemical Inactivation

Soil Aquifer Treatment

- Biological
- Adsorption
- Other?

Montebello Forebay



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A "STATE-OF-THE-ART" REVIEW
of HEALTH ASPECTS
of WASTEWATER RECLAMATION
for GROUNDWATER RECHARGE

November 1975

STATE OF CALIFORNIA

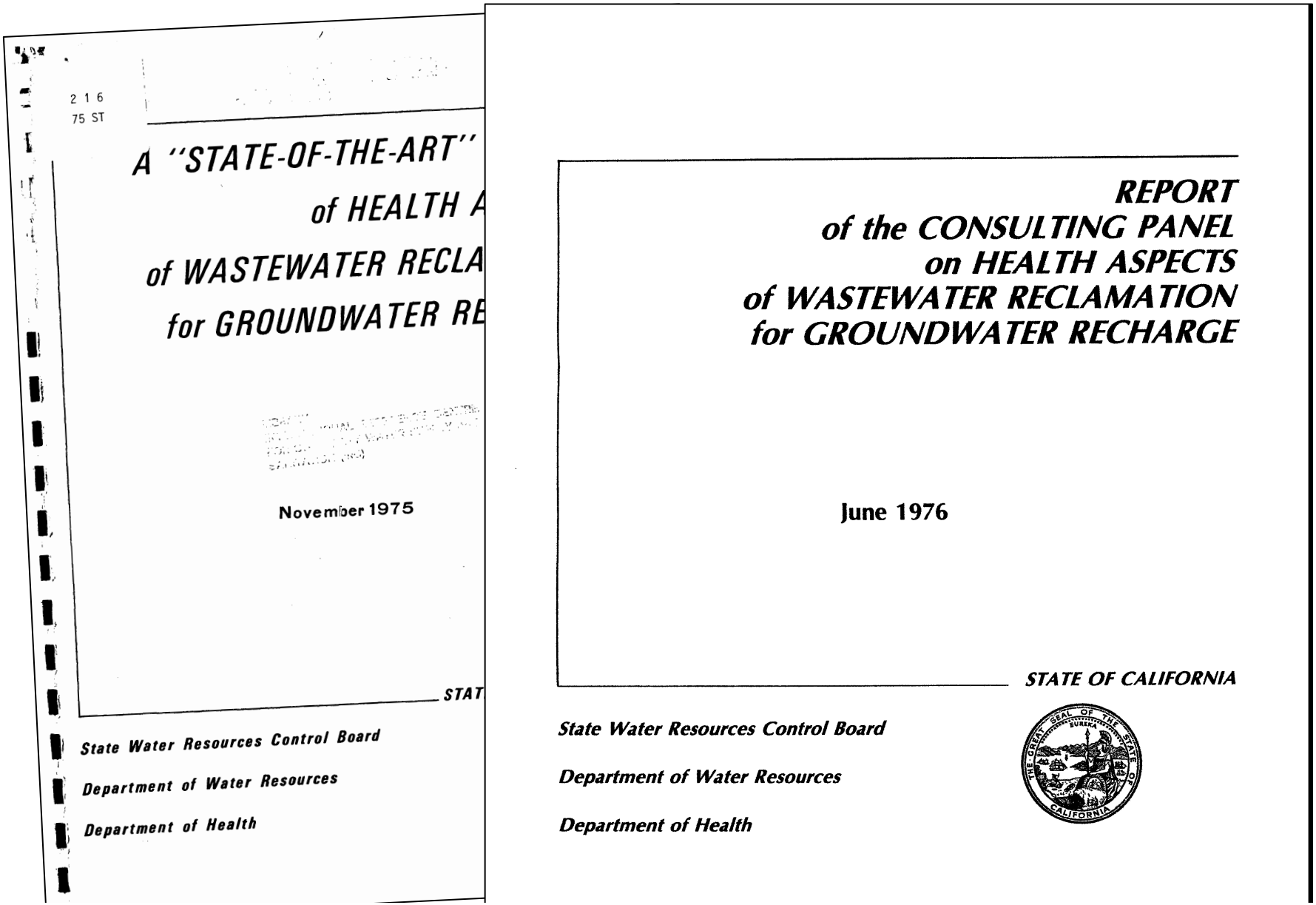
State Water Resources Control Board

Department of Water Resources

Department of Health

216-75 ST-7077

Montebello Forebay



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A "STATE-OF-THE-ART"
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November 1975

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State Water Resources Control Board

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Department of Health

REPORT
of the CONSULTING PANEL
on HEALTH ASPECTS
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June 1976

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Montebello Forebay

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Attenuation of contaminants of emerging concern during surface-spreading aquifer recharge

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Indirect potable reuse

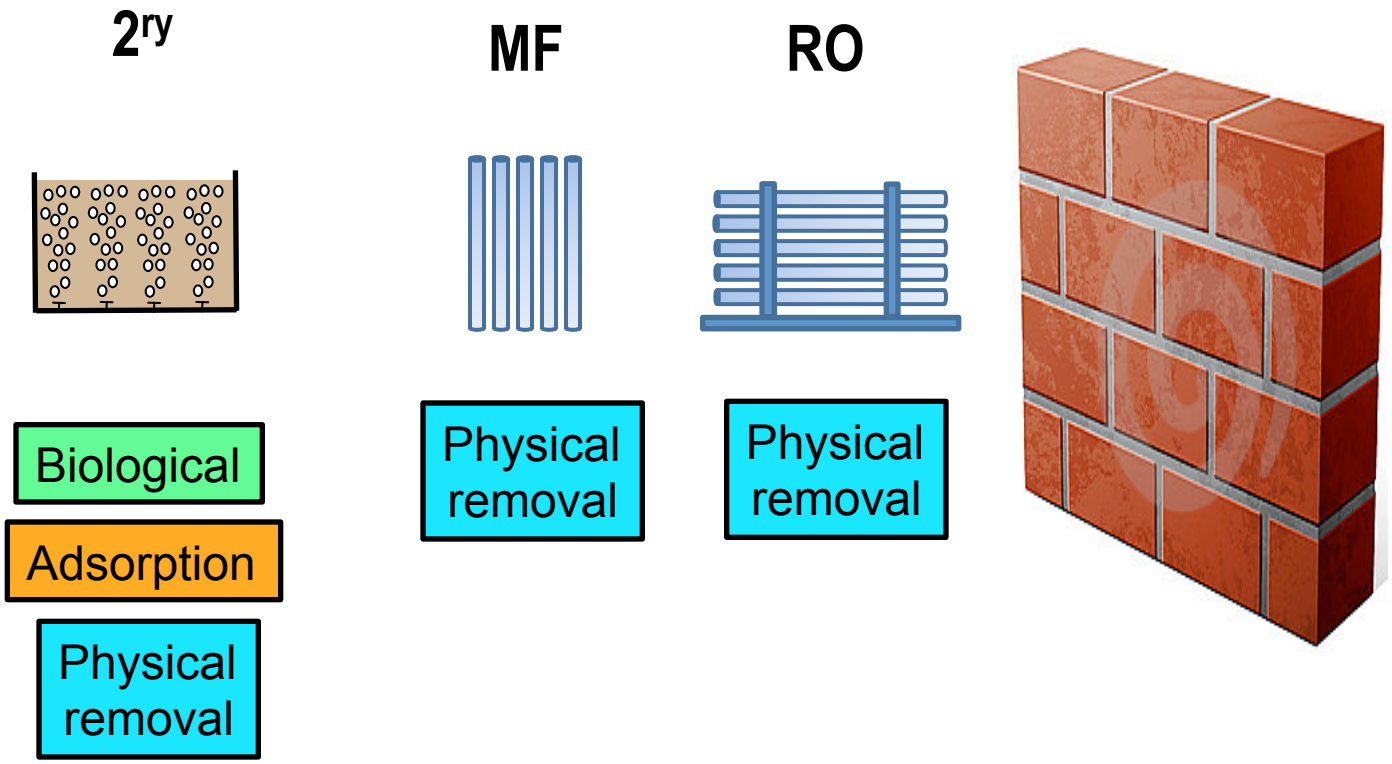
ABSTRACT

The attenuation of a diverse suite of contaminants of emerging concern (CECs) and bulk water quality changes was evaluated at a surface-spreading aquifer recharge operation across a detailed subsurface profile (9 locations), representing both short- and long-travel times (10 h to 60 days). Seventeen CECs were detected in the recharge basin and the concentrations of all were reduced during soil aquifer treatment (SAT), with 11 of the target compounds attenuated by >80% after 60 days of travel time. Select CECs (atenolol, gemfibrozil, *N*,*N*-diethly-3-methylbenzamide, meprobamate, tris(2-chloroethyl)phosphate, and primidone) and bulk water organic-carbon measurements (total organic carbon, biodegradable organic carbon, size-exclusion chromatography and fluorescence excitation–emission matrices) were identified as monitoring parameters that can be used to assess SAT performance at surface-spreading operations.

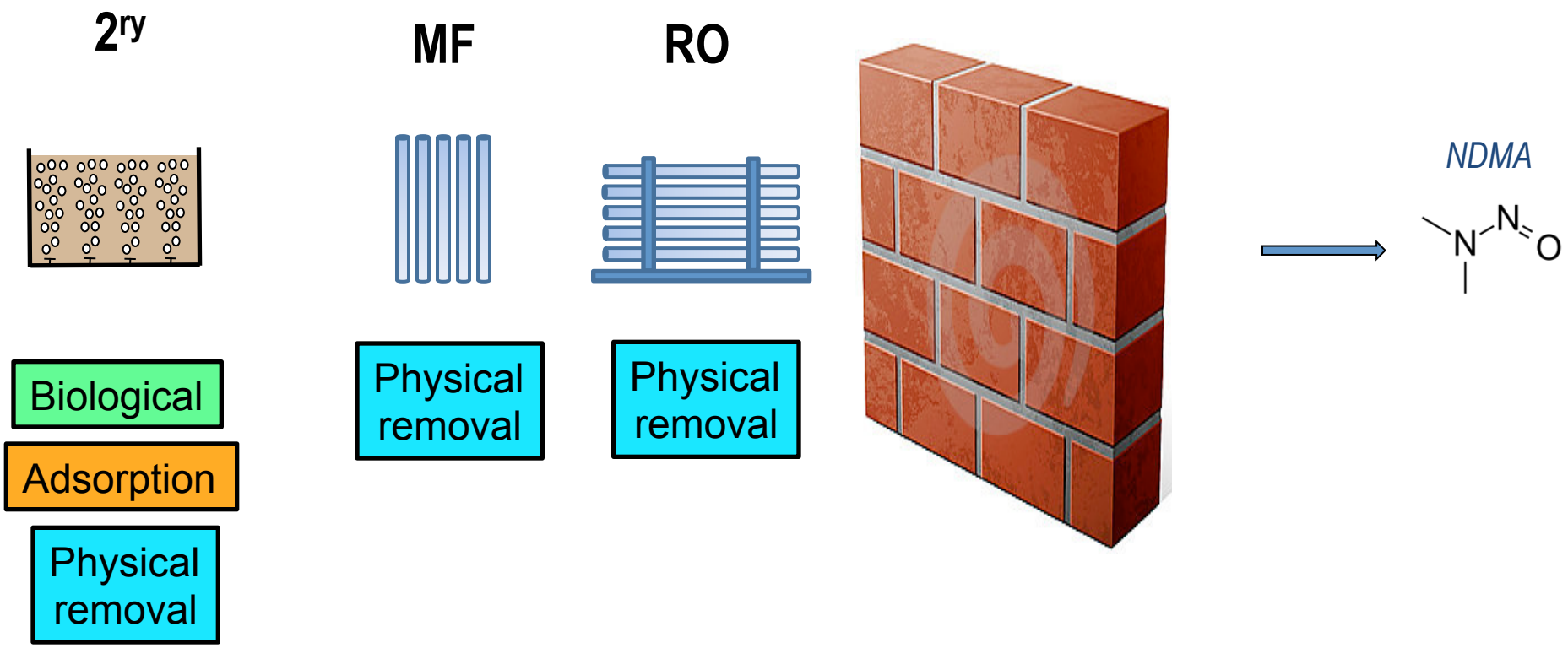
Ground Water Replenishment System

Orange Co., CA

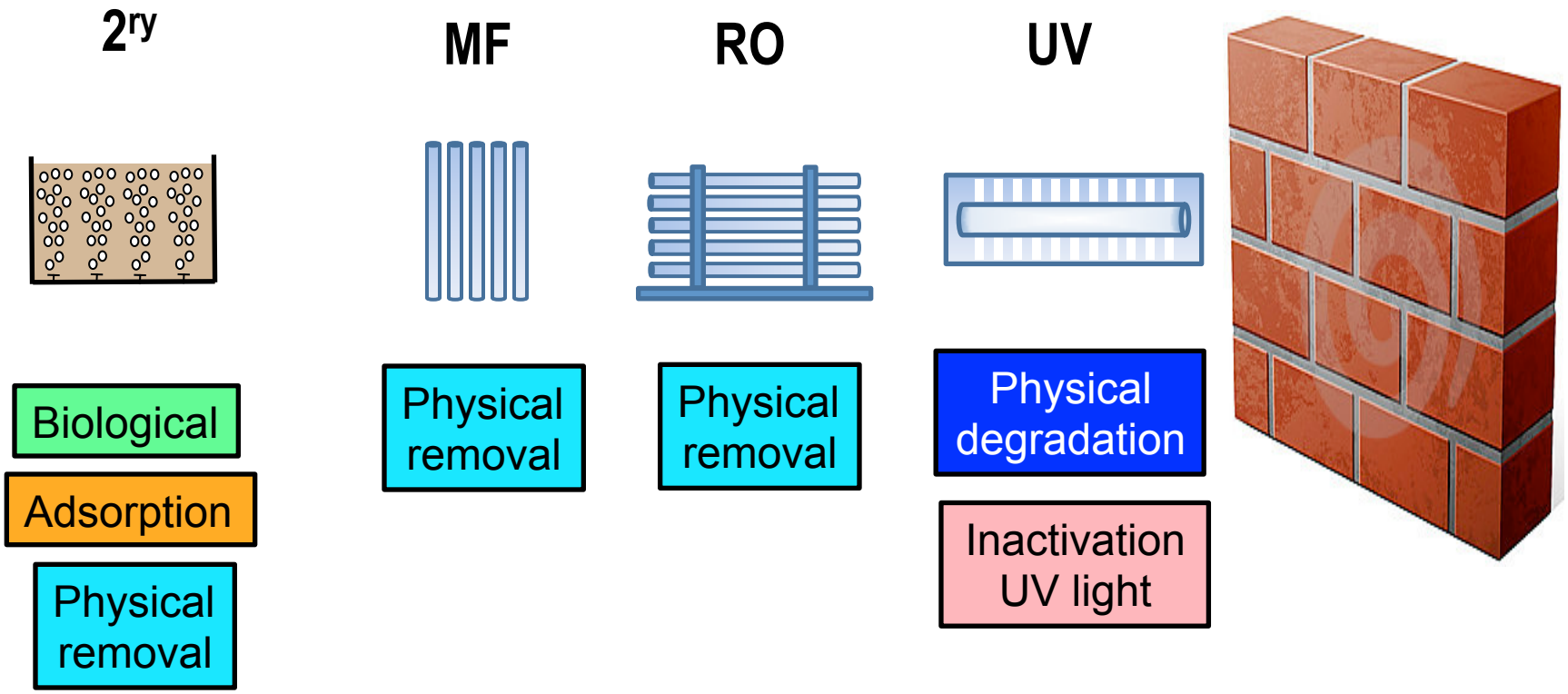
Orange County



Orange County



Orange County



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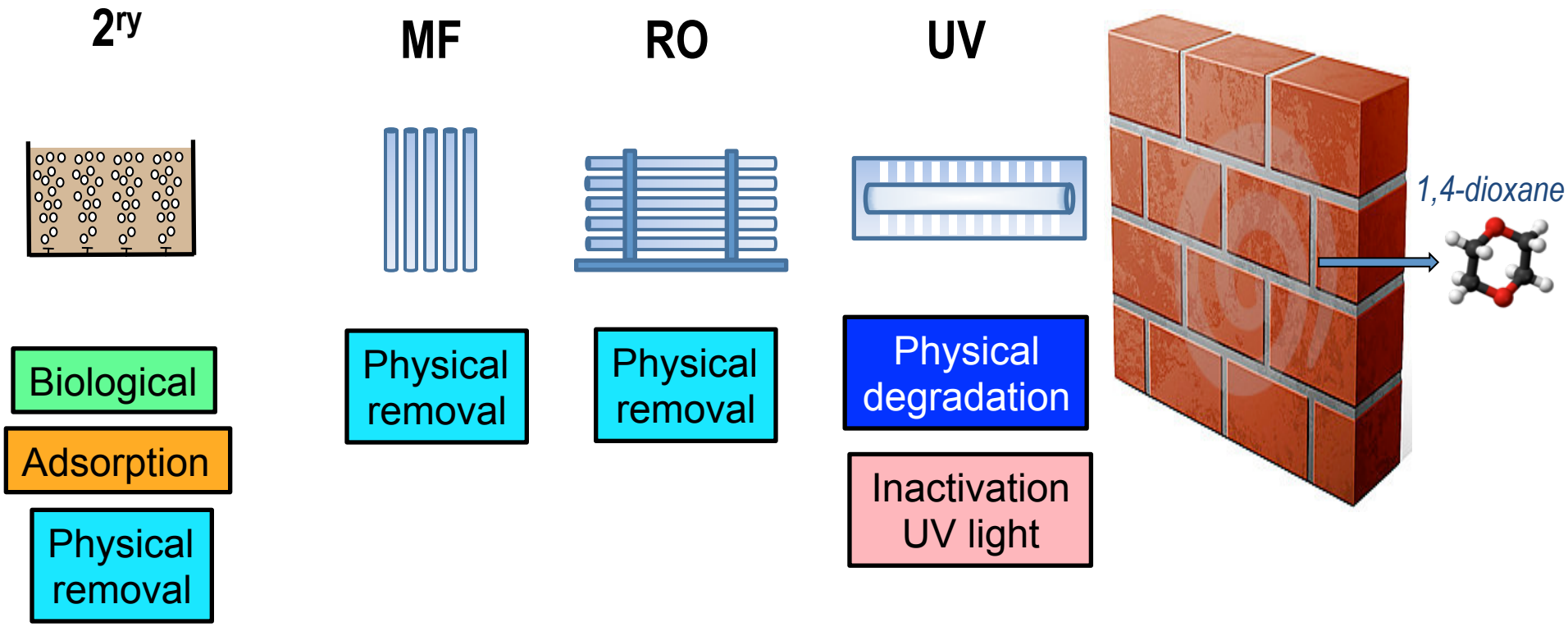

Orange County

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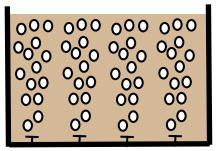
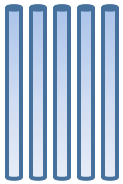


Biological

Adsorption

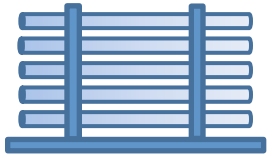
Physical removal

MF



Physical removal

RO



Physical removal

UV/AOP

Physical degradation

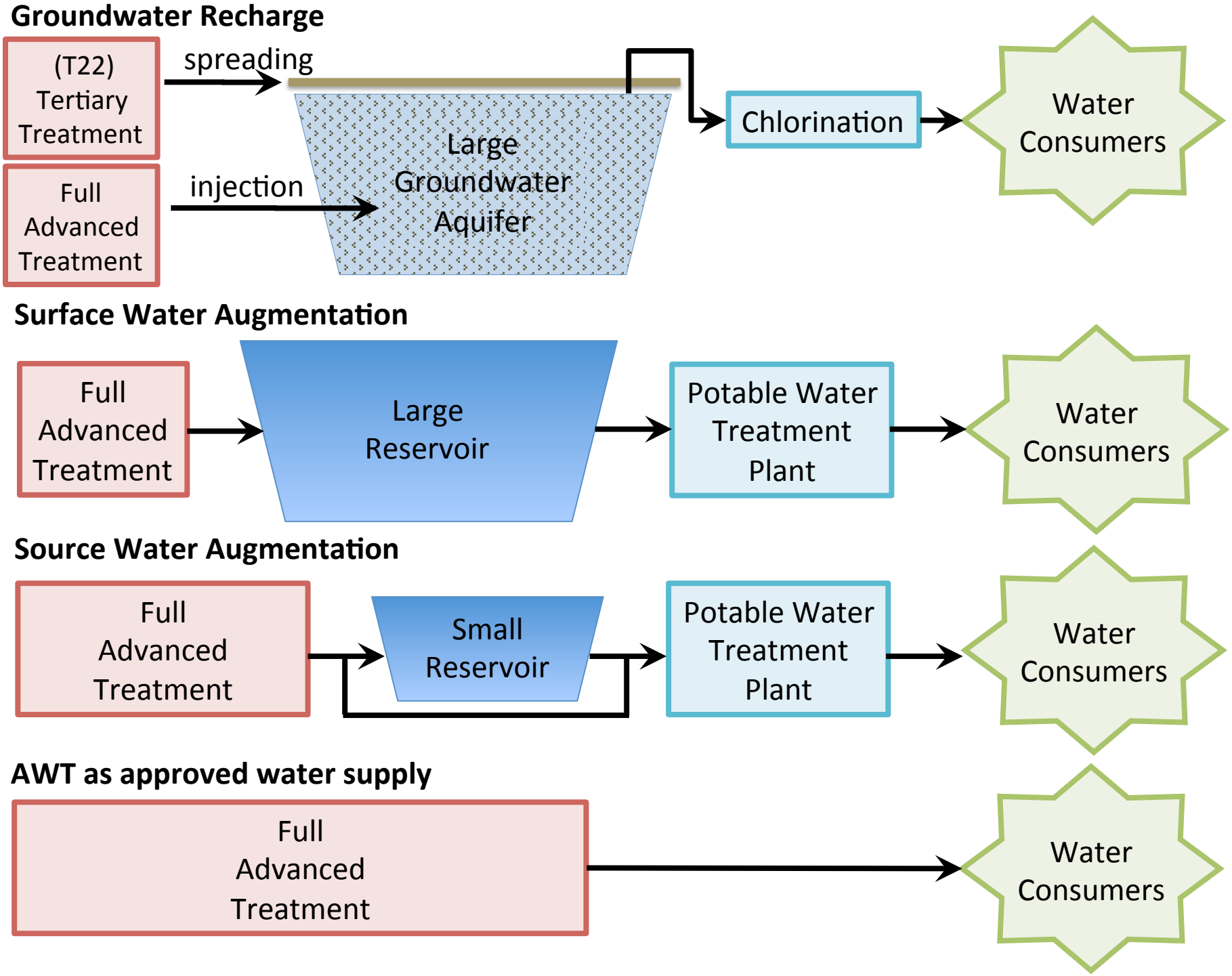
Inactivation UV light

Oxidation

History Lessons

- CECs an issue for all forms of reuse
- Robustness is the key to CEC control
- Multiple reuse options provide robust protection against CECs
- We should develop as many options as possible in toolbox to use

CURRENT RESEARCH IN ROBUST POTABLE REUSE

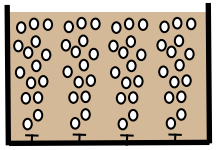

Groundwater Recharge
(T22) Tertiary Treatment
Full Advanced Treatment
spreading
injection
Large Groundwater Aquifer
Chlorination
Water Consumers
Surface Water Augmentation
Full Advanced Treatment
Large Reservoir
Potable Water Treatment Plant
Water Consumers
Source Water Augmentation
Full Advanced Treatment
Small Reservoir
Potable Water Treatment Plant
Water Consumers
AWT as approved water supply
Full Advanced Treatment
Water Consumers

Improving Robustness and CEC Control

- Two examples:
  - WRRF 12-12 Enhancing the Soil Aquifer Treatment Process for Potable Reuse
  - WRRF 14-12 Demonstrating Redundancy and Monitoring to Achieve Reliable Potable Reuse

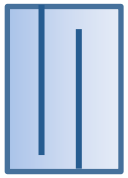
Enhancing Soil Aquifer Treatment for Potable Reuse (WRRF 12-12)

2ry



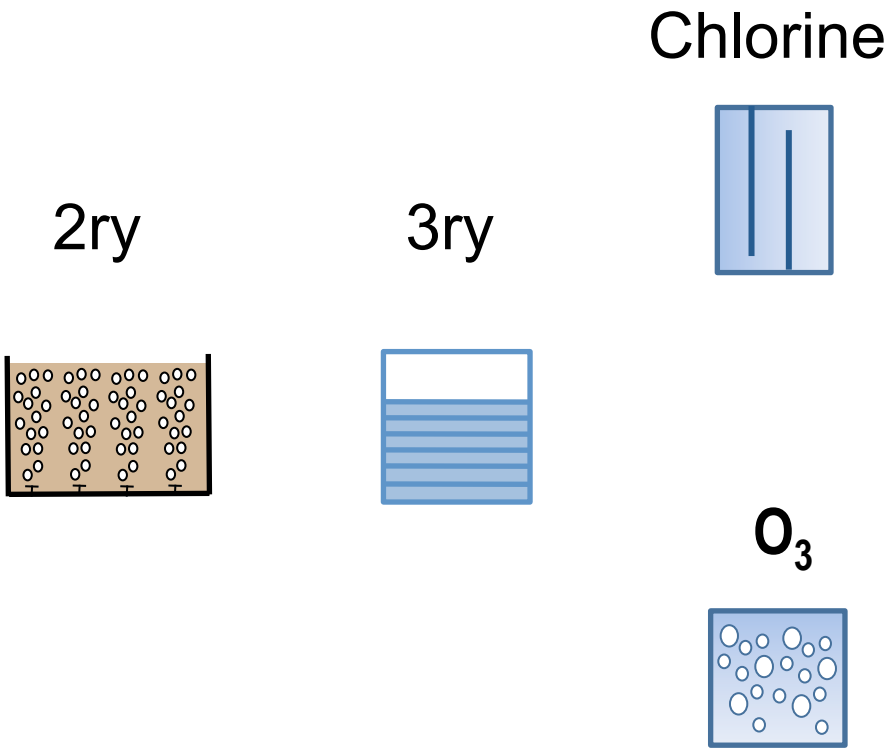
3ry

Chlorine



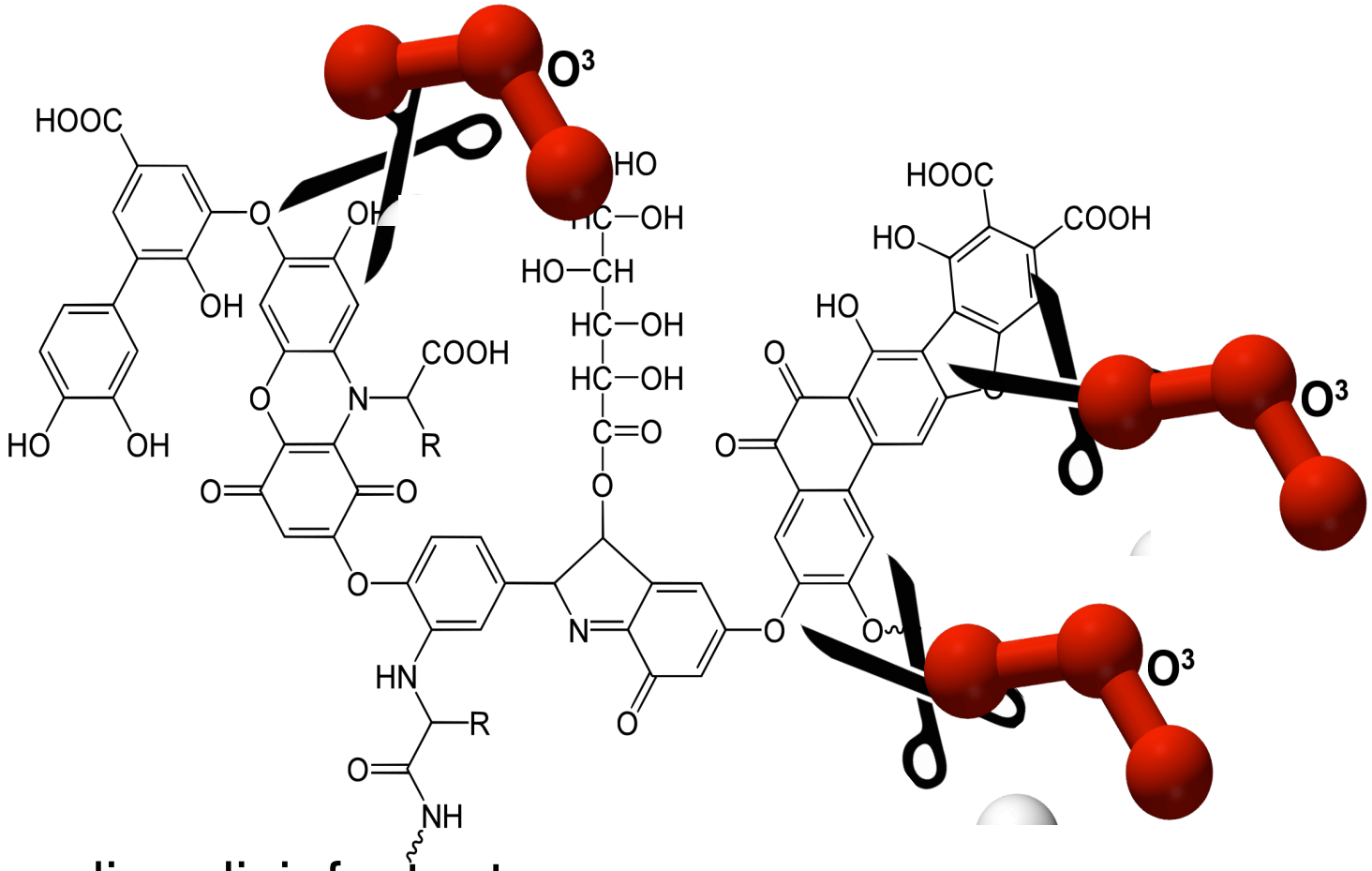
Soil Aquifer Treatment

Enhancing Soil Aquifer Treatment for Potable Reuse (WRRF 12-12)

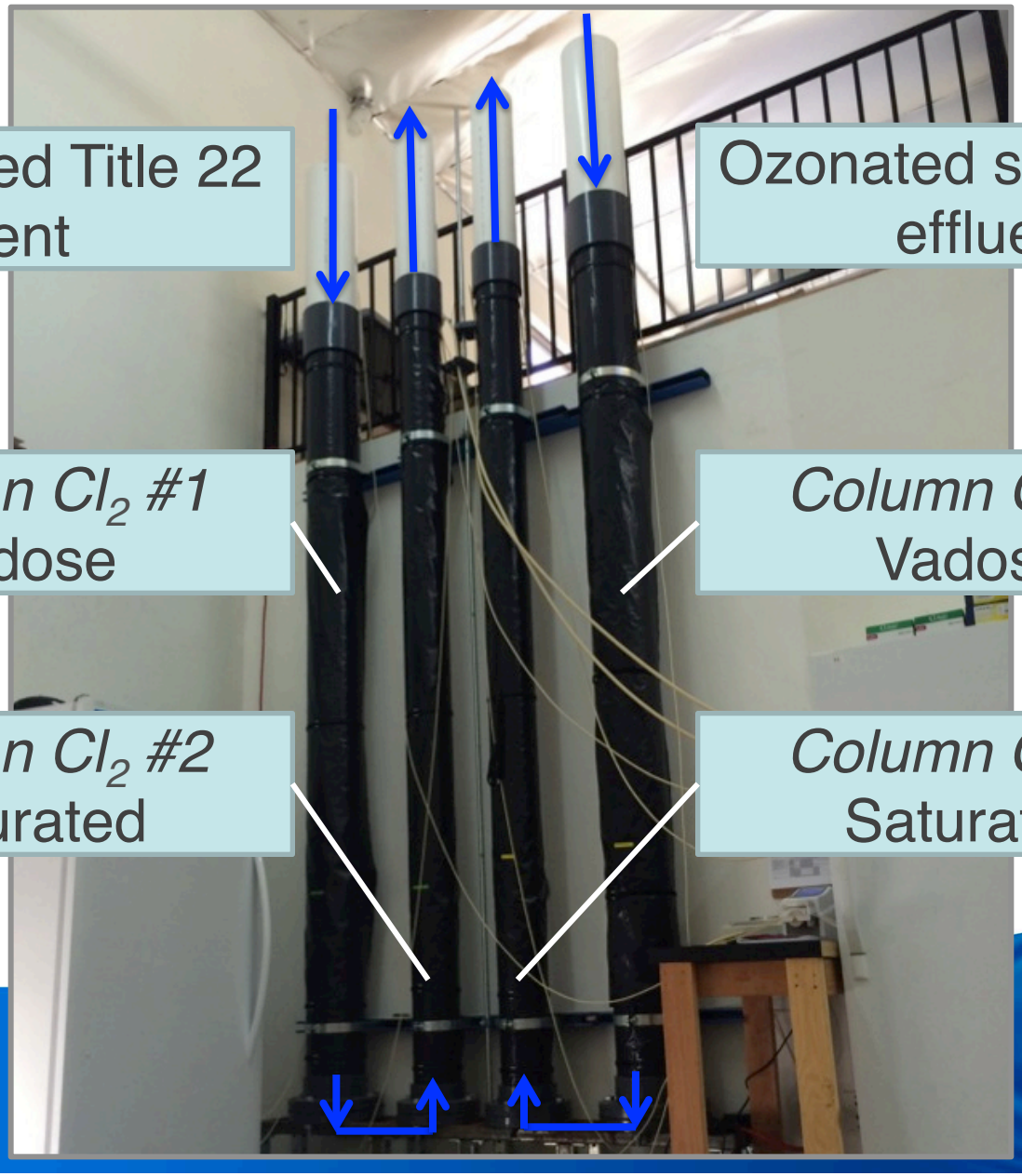


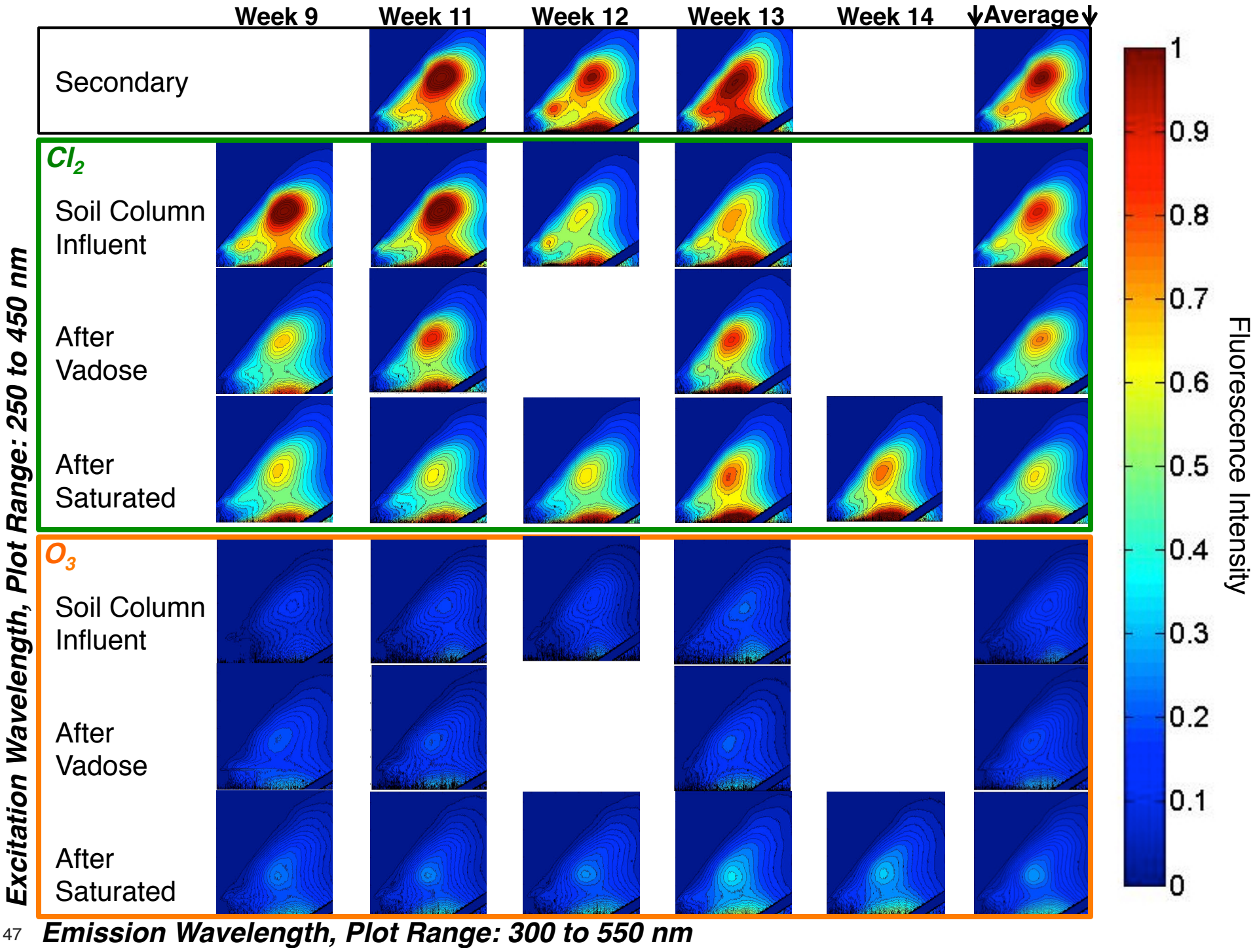
Soil Aquifer Treatment

What does ozone do to TOC?

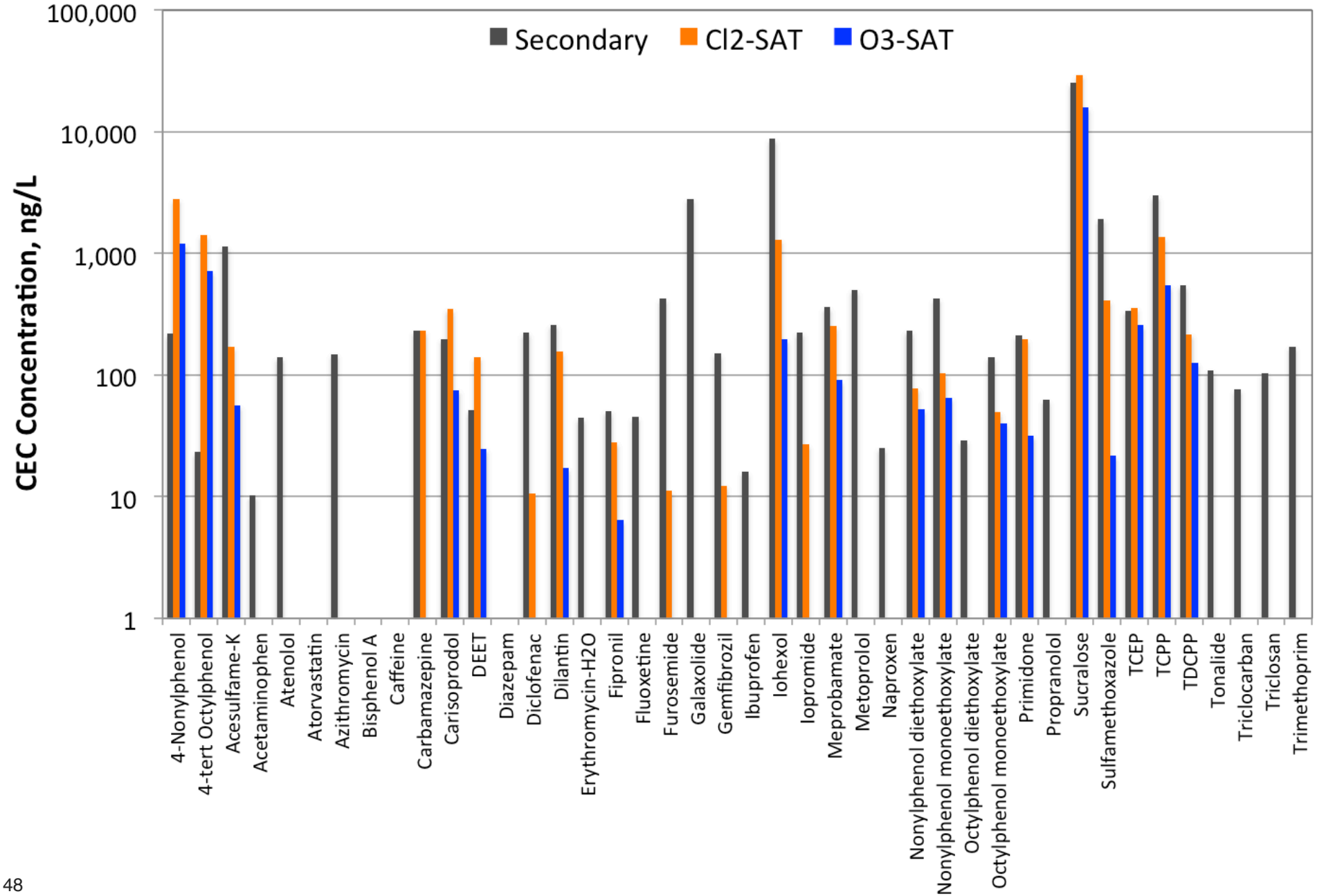


- Outstanding disinfectant
- Transforms bulk organic matter, making it more amenable to biological oxidation
- Effective at oxidizing a range of trace organic chemicals

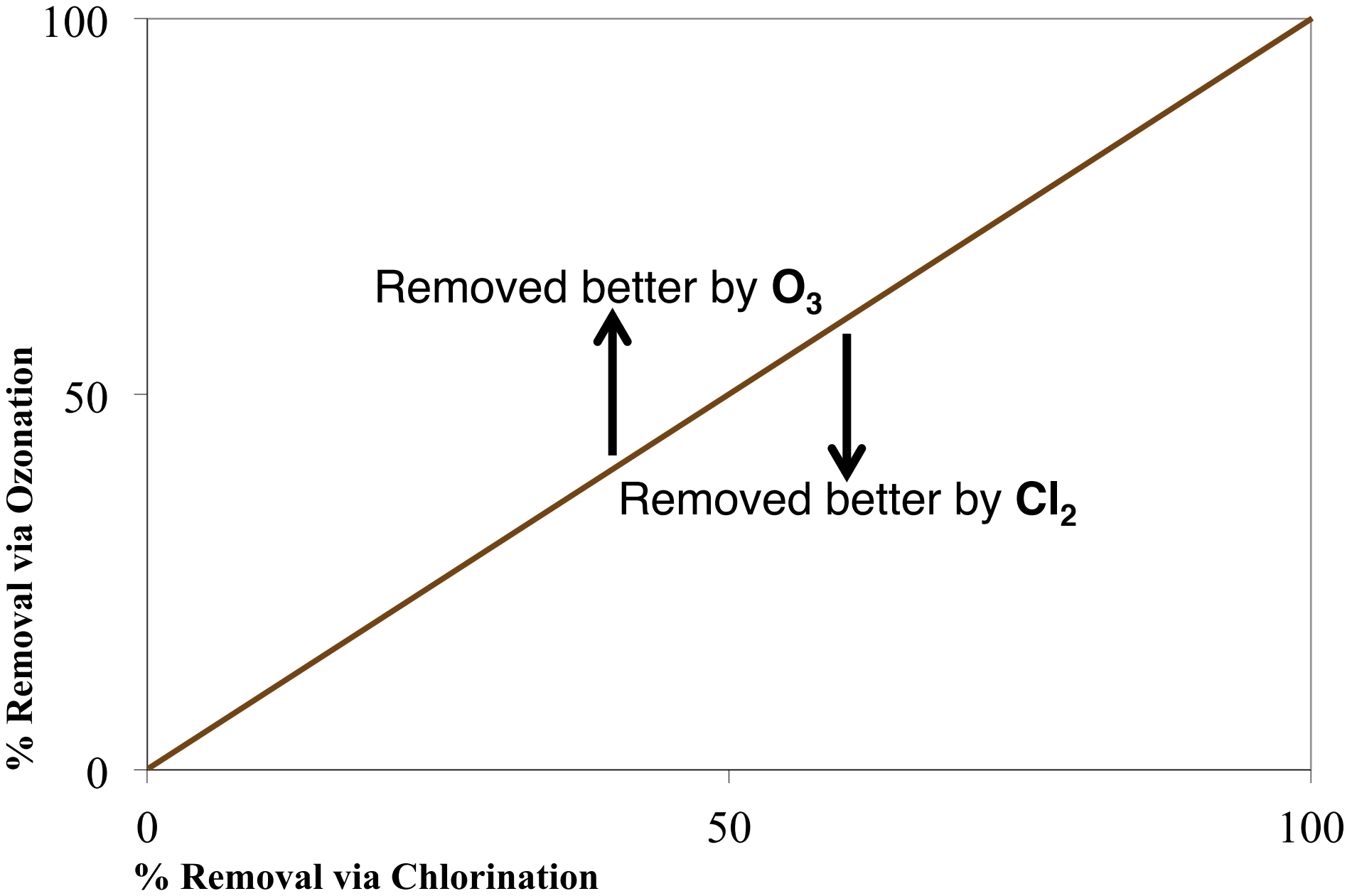

Dechlorinated Title 22 effluent
Ozonated secondary effluent
Column Cl_2 #1 Vadose
Column O_3 #1 Vadose
Column Cl_2 #2 Saturated
Column O_3 #2 Saturated


Week 9
Week 11
Week 12
Week 13
Week 14
Average
Secondary
Cl2
Soil Column Influent
After Vadose
After Saturated
O3
Soil Column Influent
After Vadose
After Saturated
Excitation Wavelength, Plot Range: 250 to 450 nm
Emission Wavelength, Plot Range: 300 to 550 nm
Fluorescence Intensity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

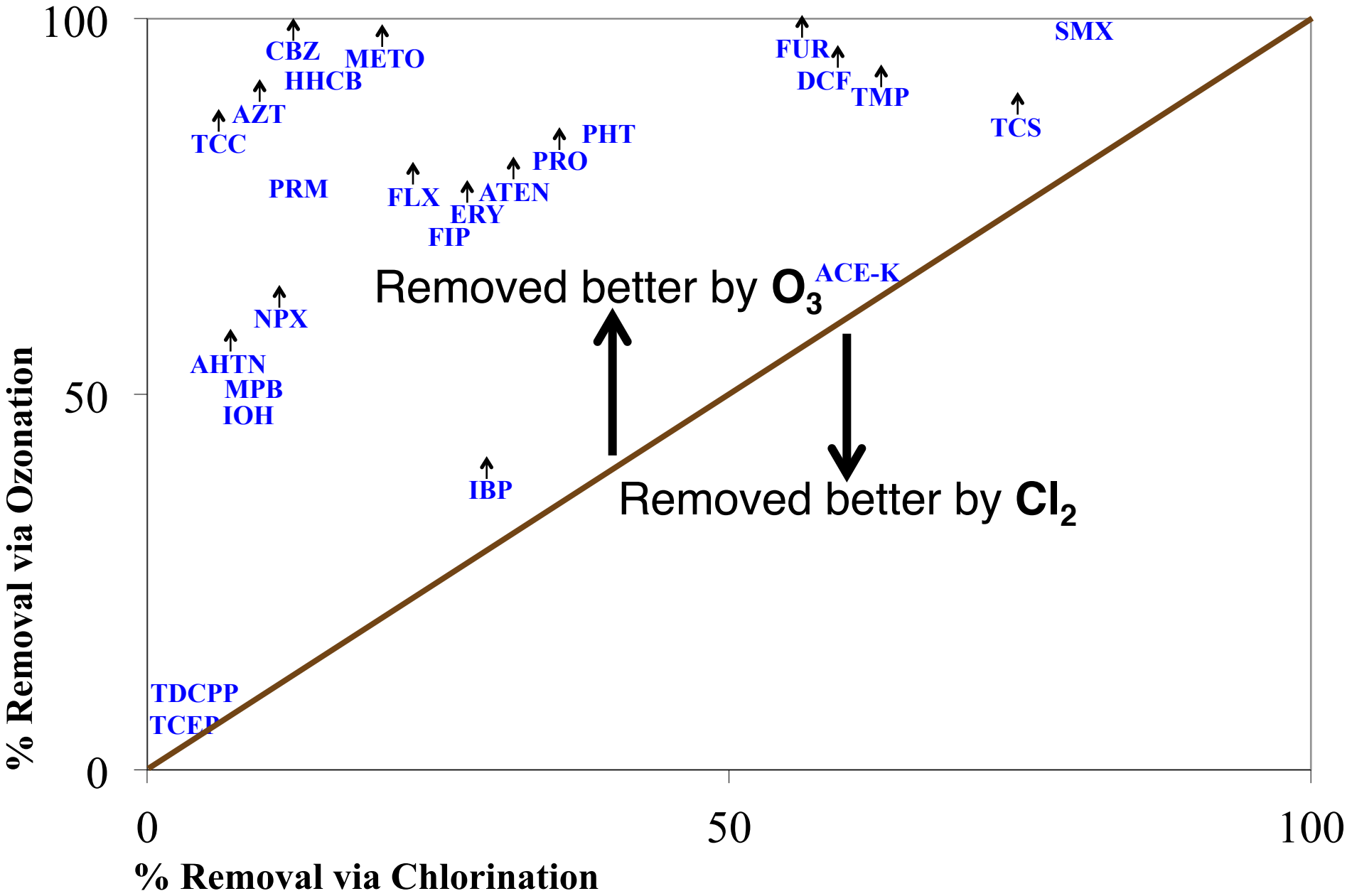
CEC Attenuation



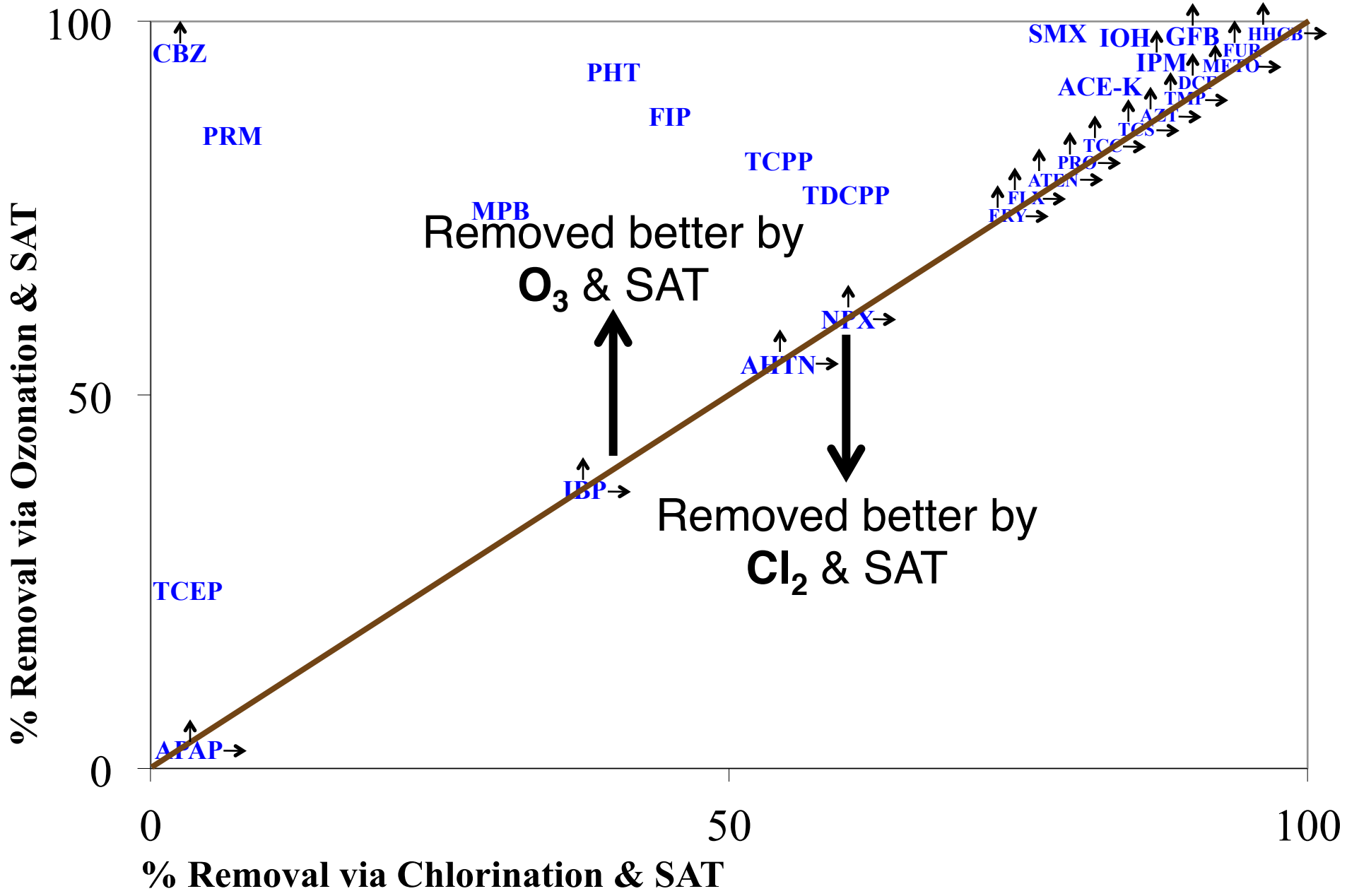
CEC Attenuation



CEC Attenuation



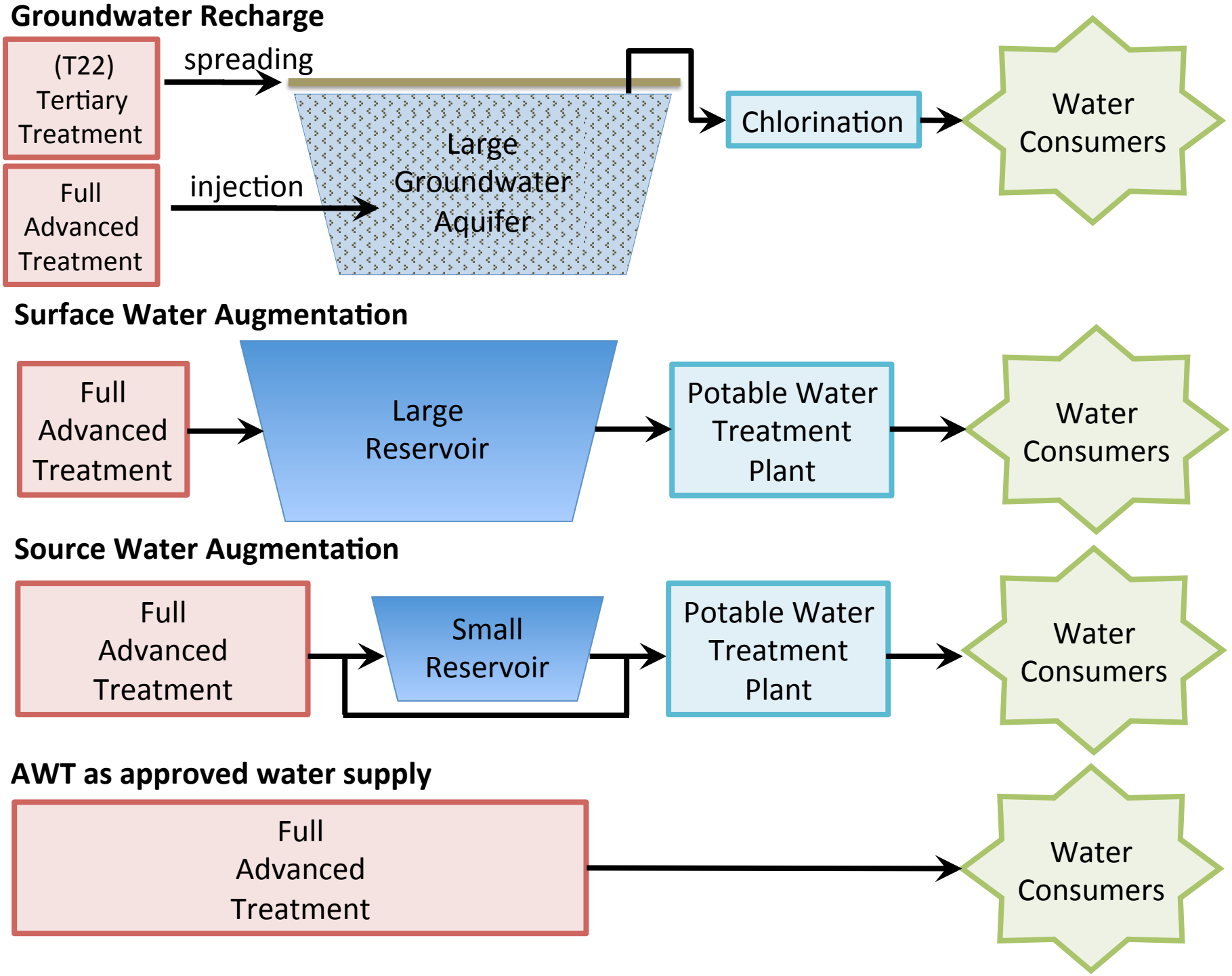
CEC Attenuation



Enhancing SAT Robustness

- Ozone should be considered to enhance "Nature"
  - Remove more trace organics
  - Remove more TOC through the SAT process *allows more potable reuse with less blending*
  - Cost effective for advanced treatment

	Ozone	Sodium Hypochlorite
Applied dose, mg/L	10	10
Cost, $/AF	28	23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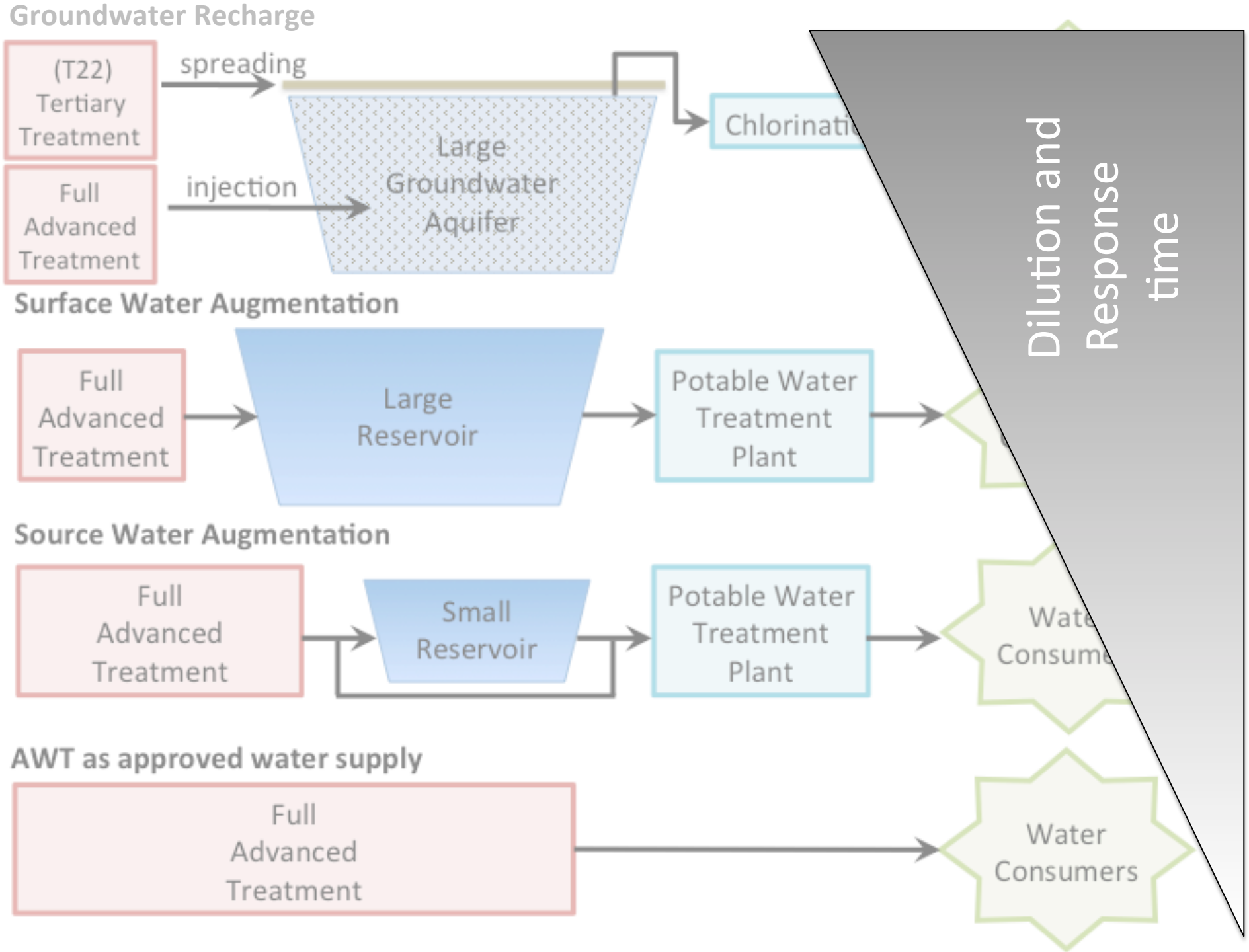
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Potable Water Treatment Plant
Wate
Consume
AWT as approved water supply
Full Advanced Treatment
Water Consumers
Dilution and Response time

What are the paths to reliability?

Does Dilution Work?

	Raw	FAT Effluent	Post-Dilution
Typical Conditions			
Safe?			

Does Dilution Work?

	Raw	FAT Effluent	Post-Dilution
Failure Conditions		 ***Process Failure***	
Safe?			

Enhanced treatment provides same benefit

	Raw	Enhanced Treatment
Typical Conditions		
Safe?		

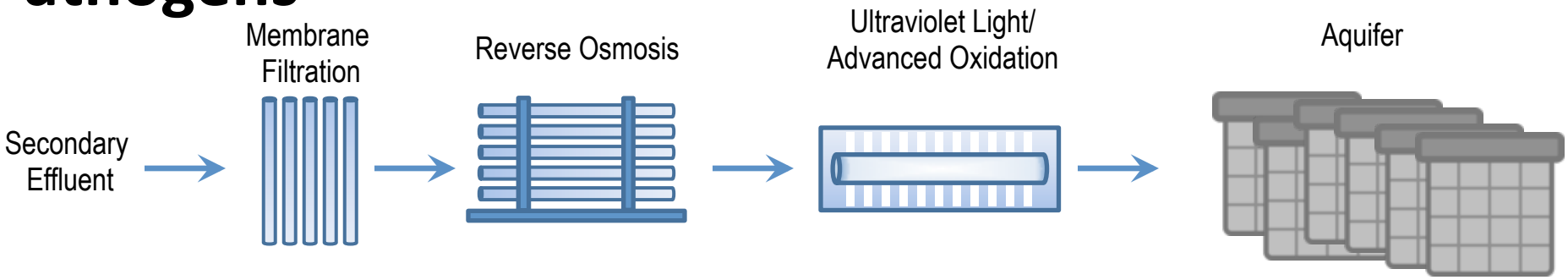
Enhanced treatment provides same benefit

	Raw	Enhanced Treatment
Failure Conditions		 *Process Failure*
Safe?		

What Else Does the AWPF Concept Consider?

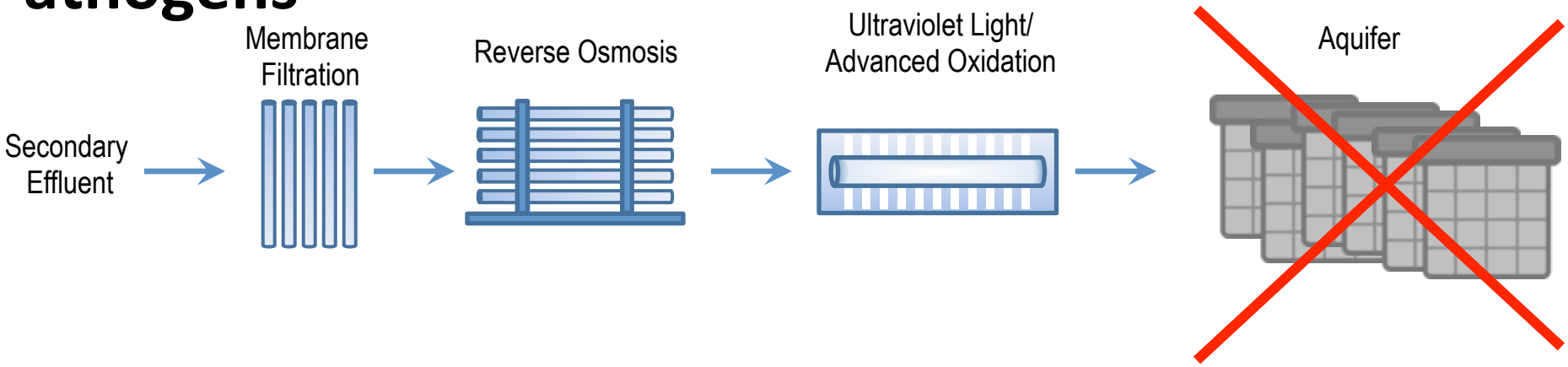
New treatment challenges for reuse

Pathogens



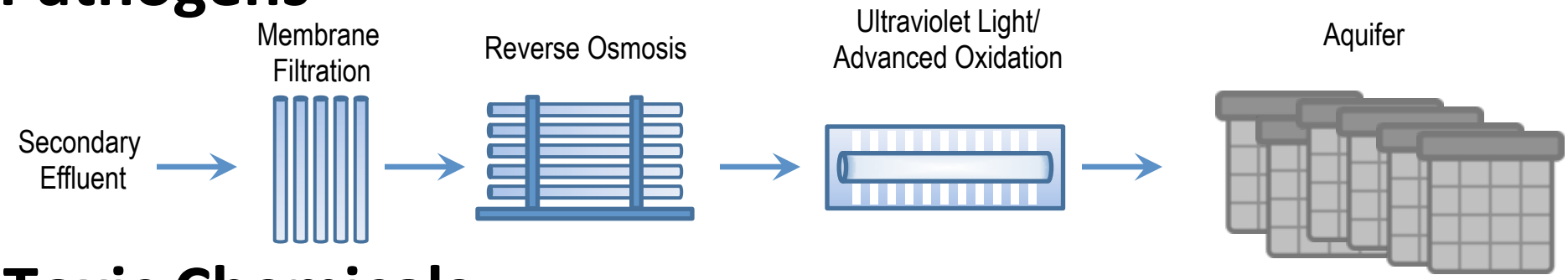
New treatment challenges for reuse

Pathogens

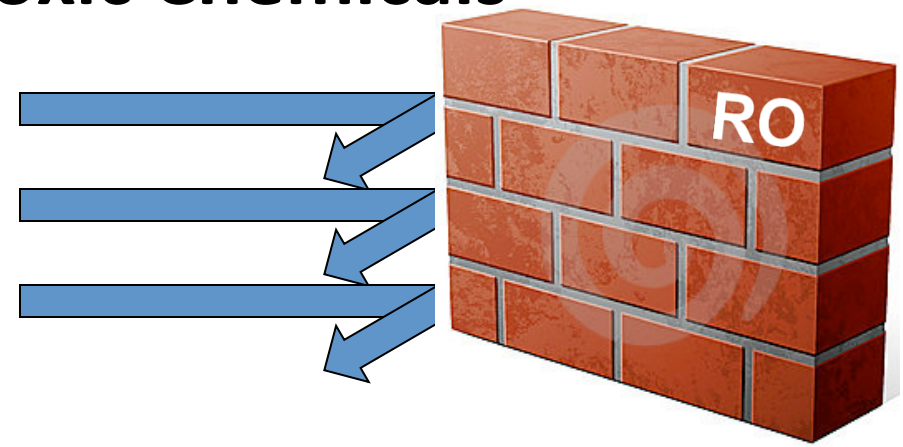


New treatment challenges for reuse

Pathogens

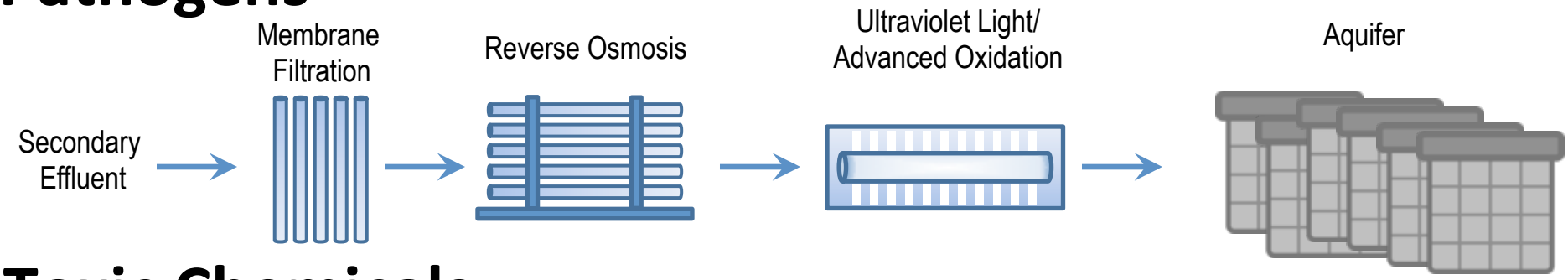


Toxic Chemicals

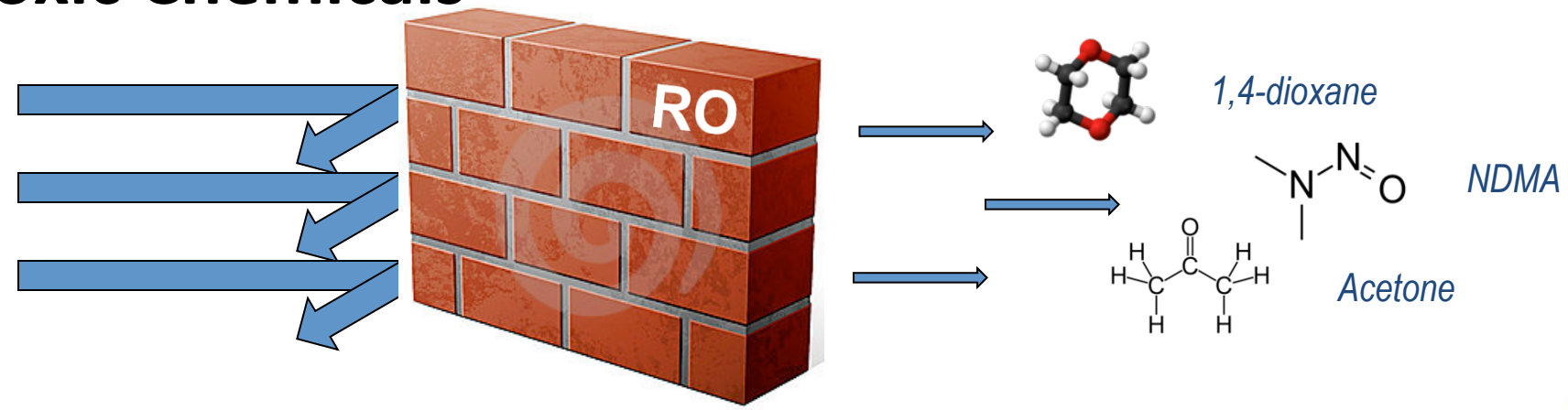


New treatment challenges for reuse

Pathogens

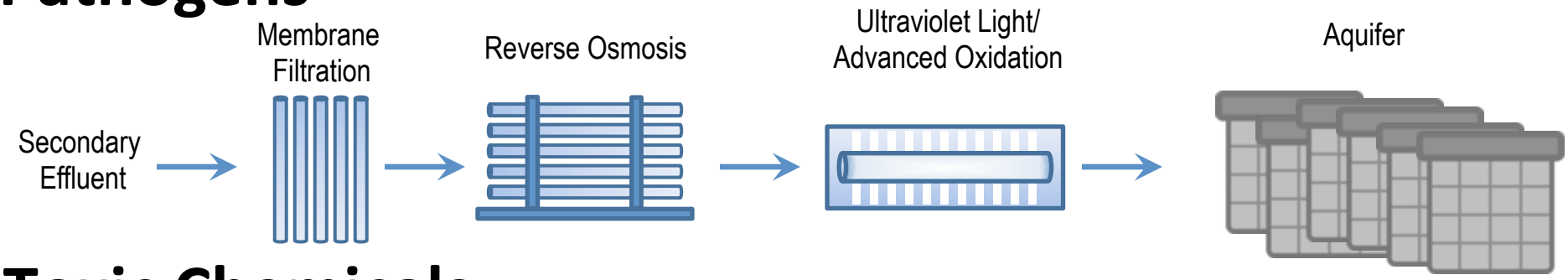


Toxic Chemicals

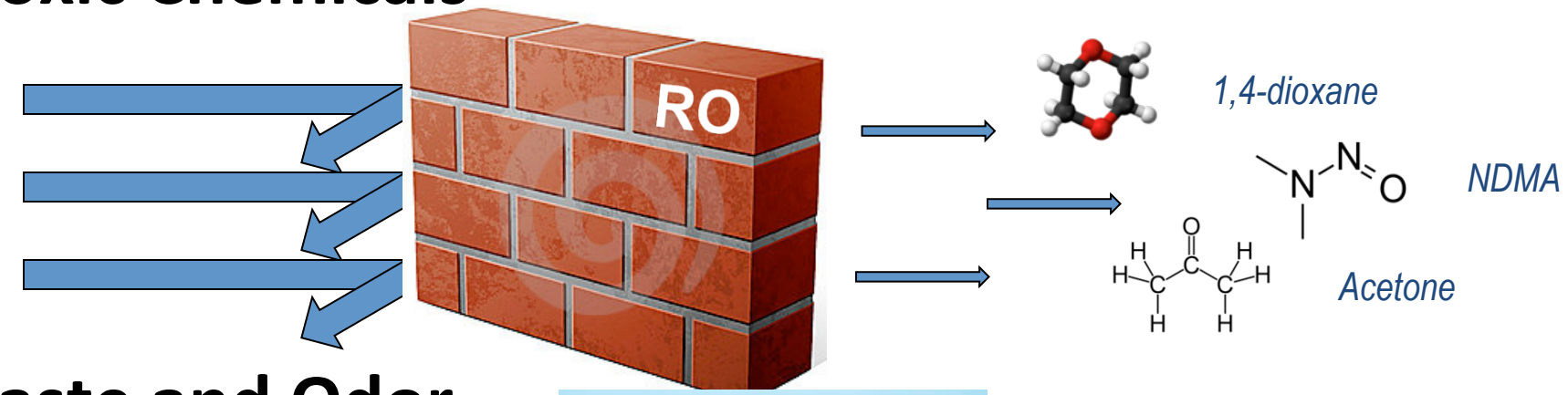


New treatment challenges for reuse

Pathogens



Toxic Chemicals



Taste and Odor

WateReuse Research Project 14-12

Title: Demonstrating Redundancy and Monitoring to Achieve Reliable Potable Reuse

WATEREUSE

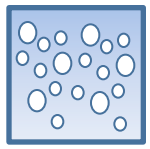
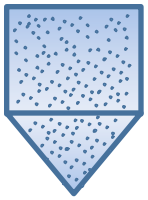
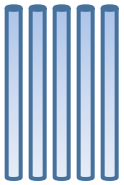
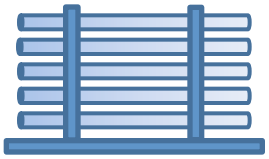
Project Goal

To leverage industry "state of the art" to demonstrate how a combination of treatment redundancy and enhanced monitoring techniques can *reliably* achieve potable reuse treatment objectives

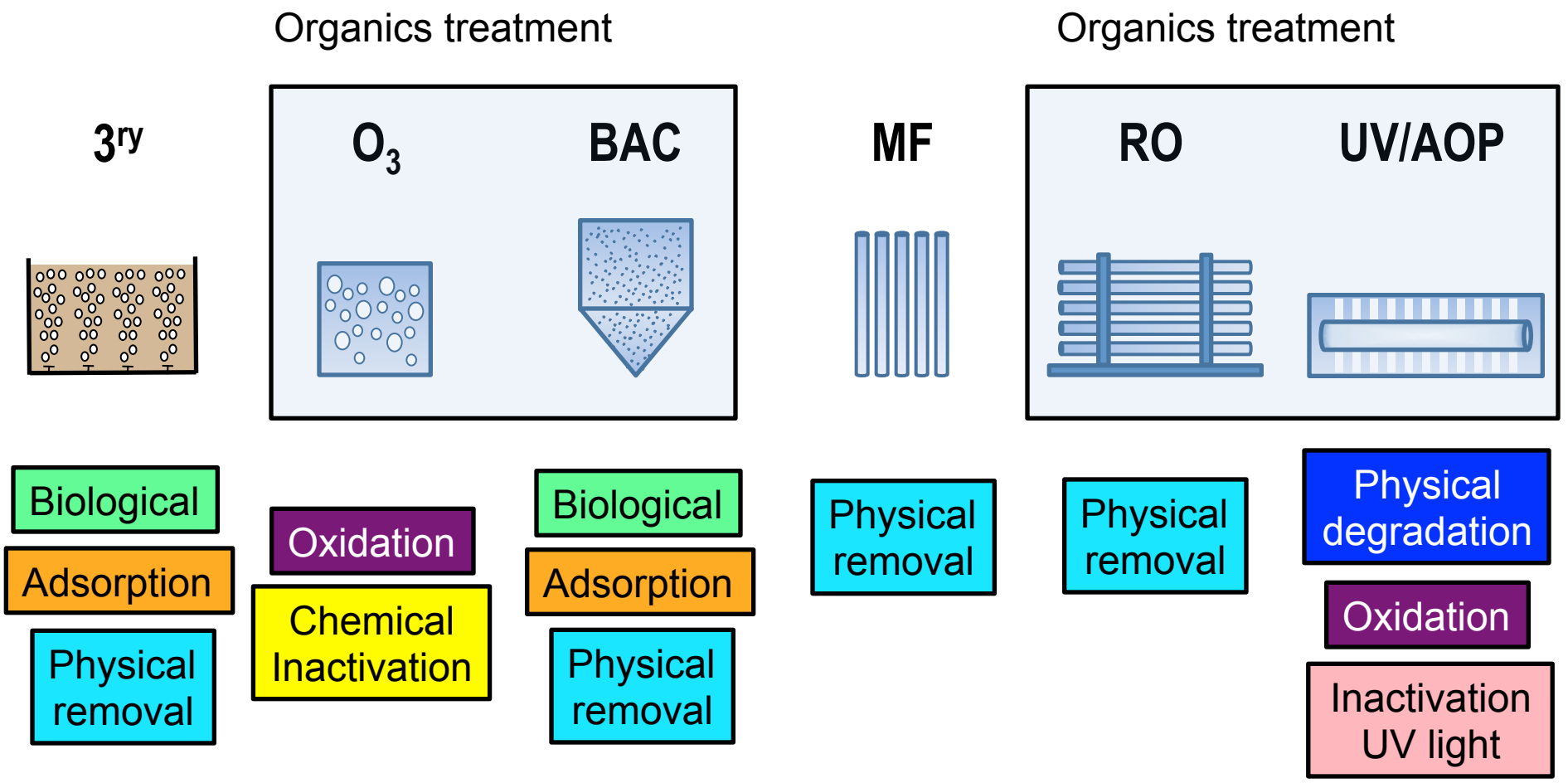
Robustness: Incorporating more strength

Pretreatment

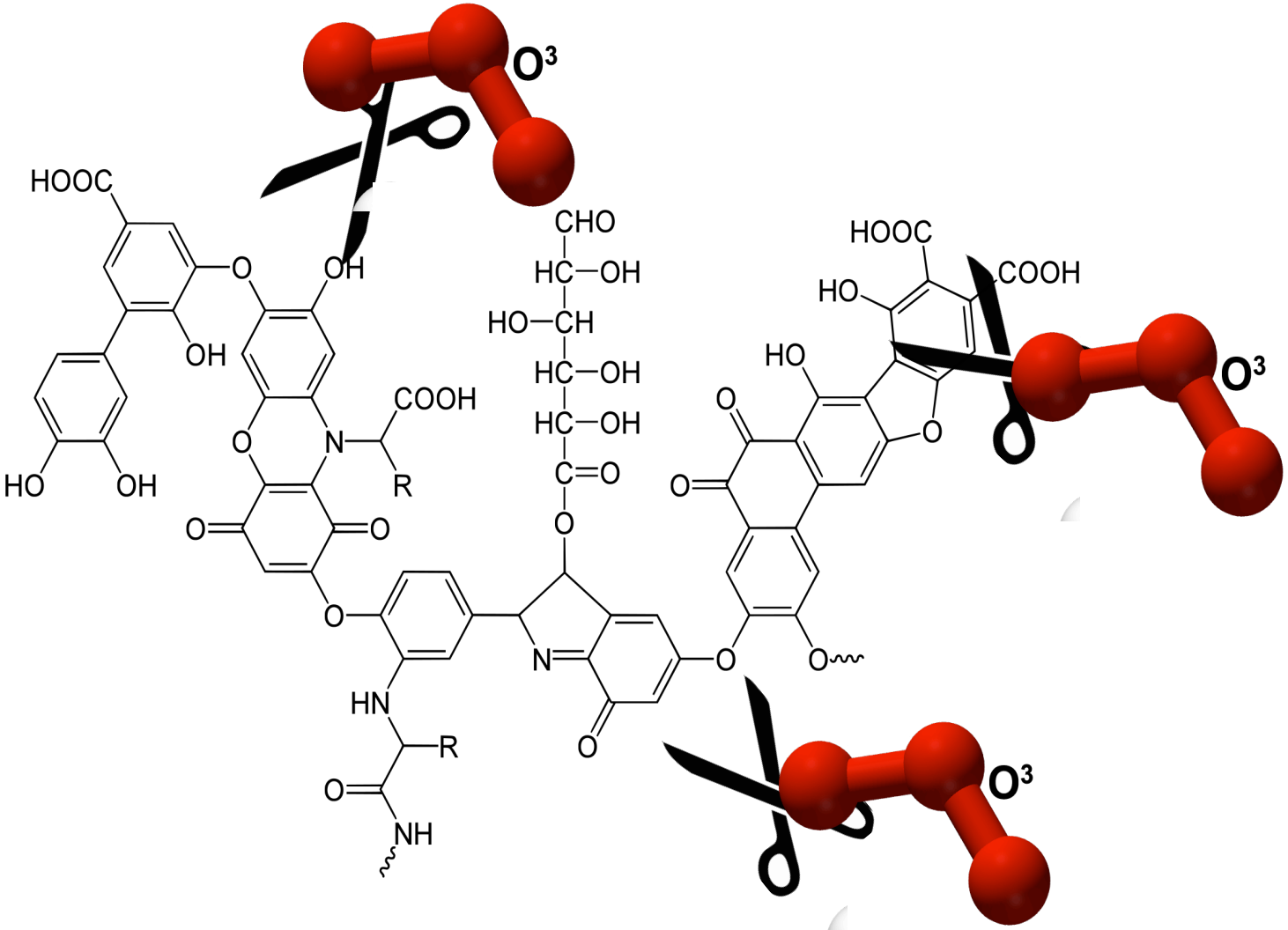
Full advanced treatment

3ry	O_3	BAC	MF	RO	UV/AOP
					
Biological Adsorption Physical removal	Oxidation Chemical Inactivation	Biological Adsorption Physical removal	Physical removal	Physical removal	Physical degradation Oxidation Inactivation UV light

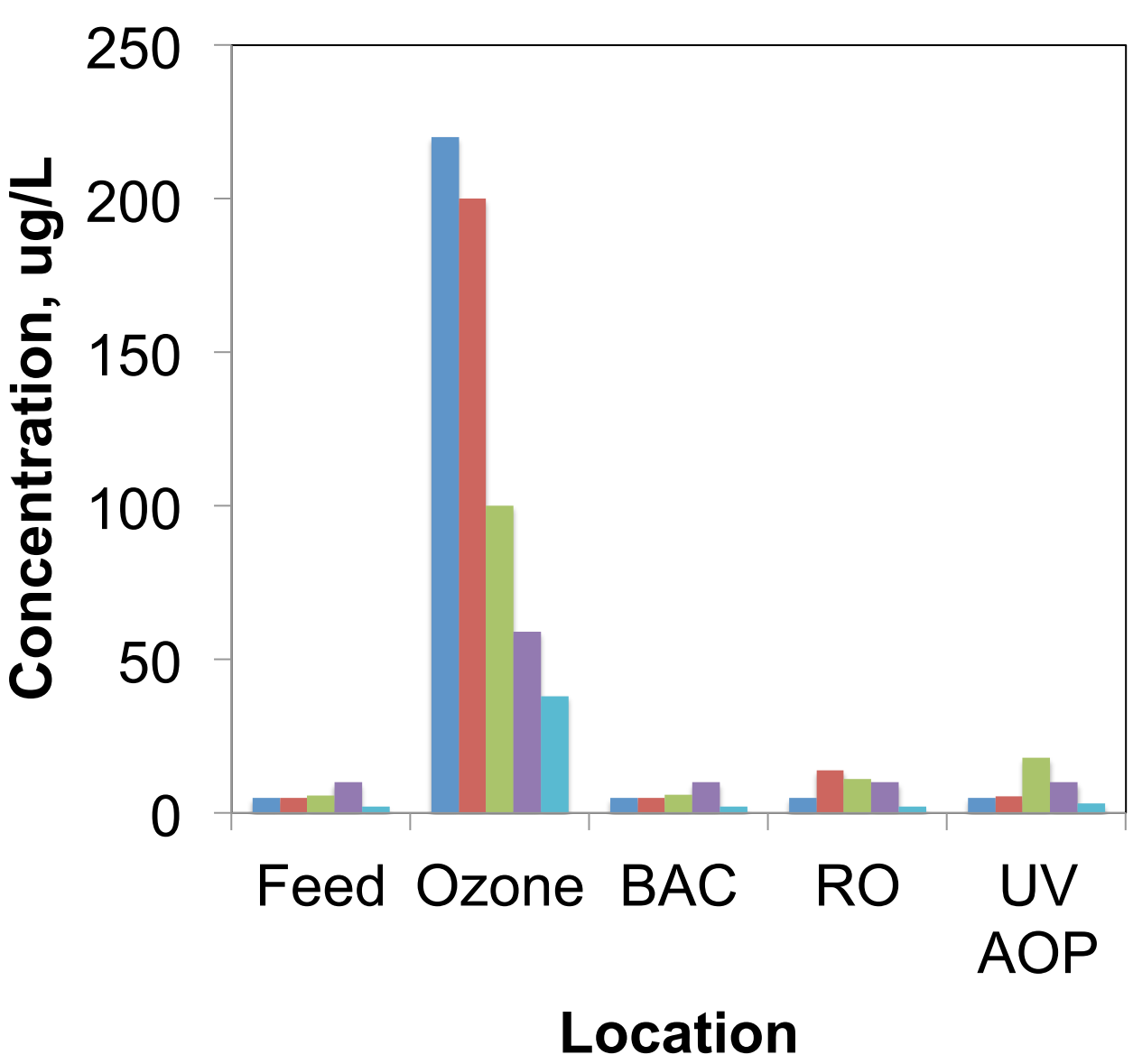
Robustness:
Proactively mitigates next “unknown”

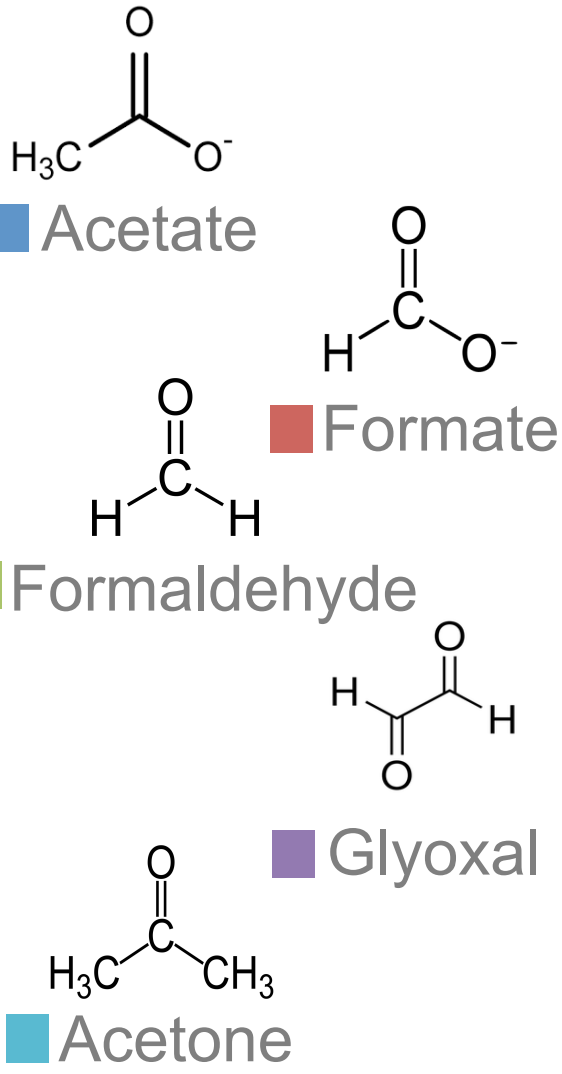


What does ozone do to TOC?



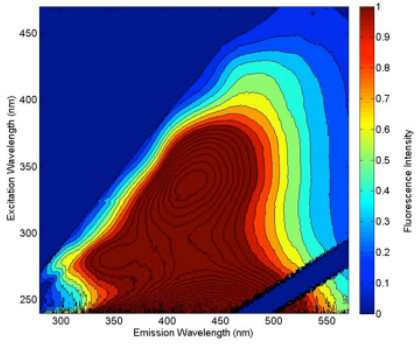
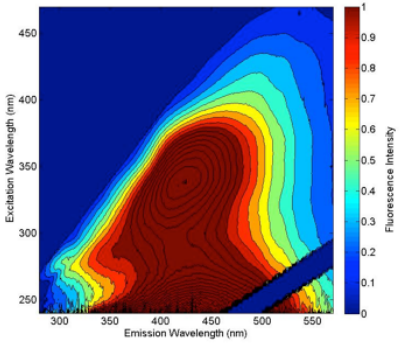
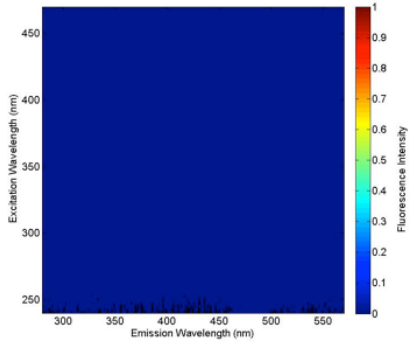
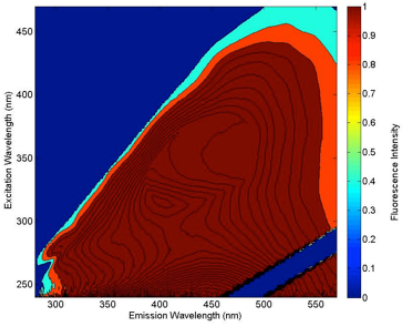
Oxidation Byproducts Are Yummy!



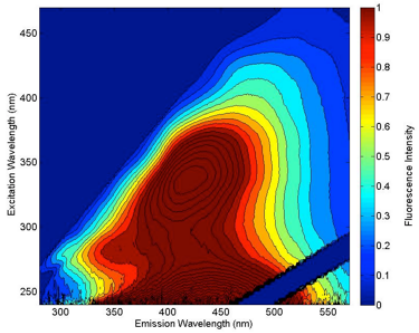
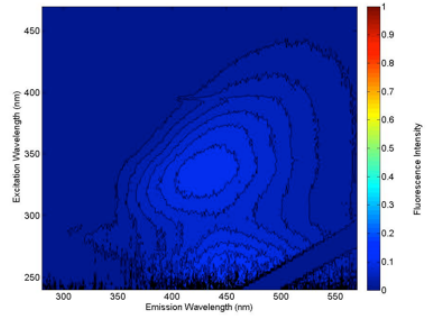
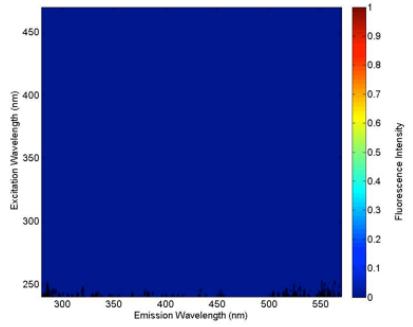
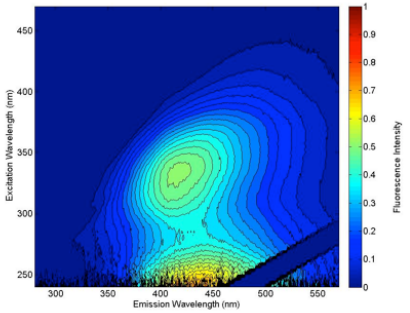


EfOM Transformation by Fluorescence

(a) Without ozone/BAC pretreatment

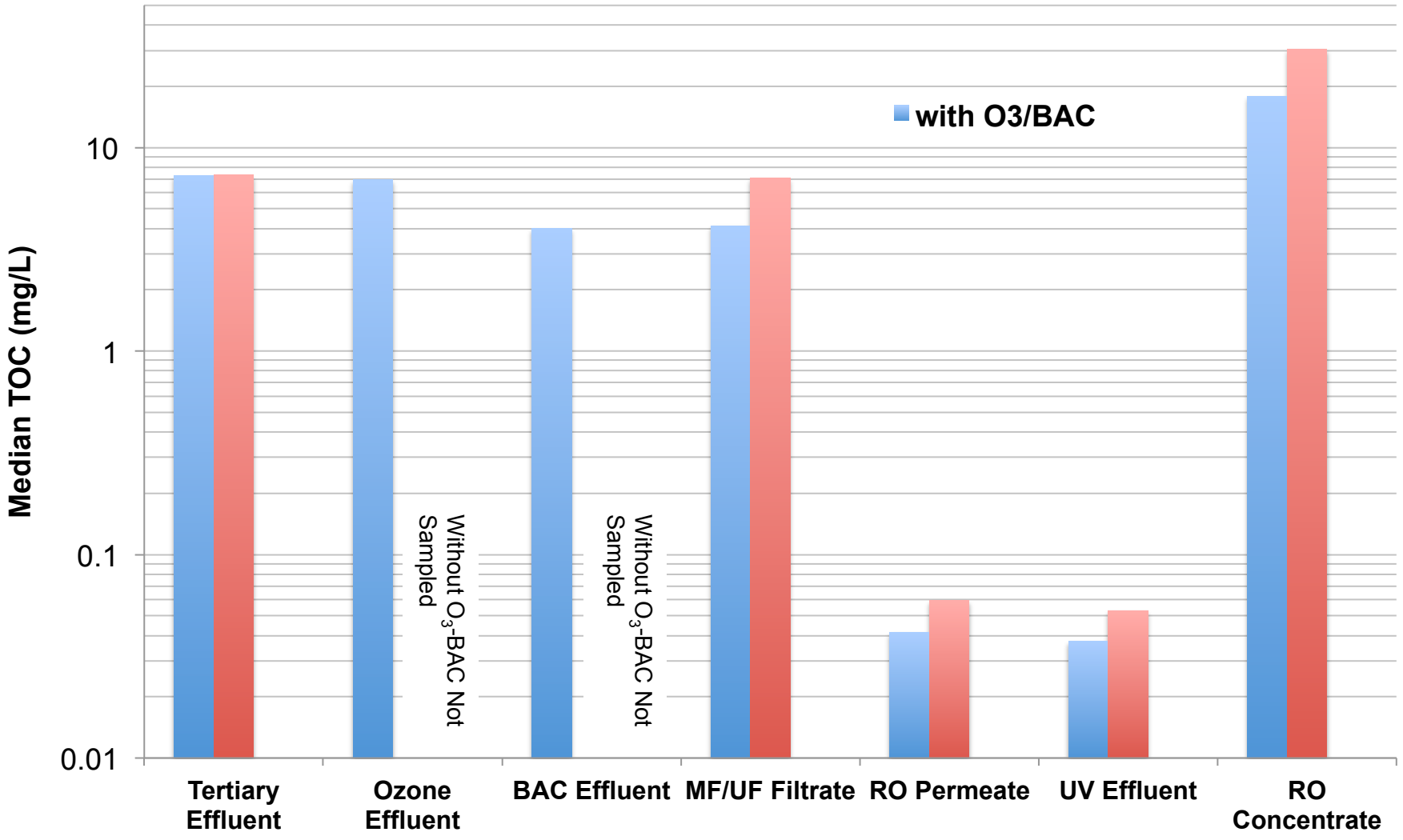
Tertiary Effluent	RO Feed	RO Permeate	RO Concentrate
			

(b) With ozone/BAC pretreatment

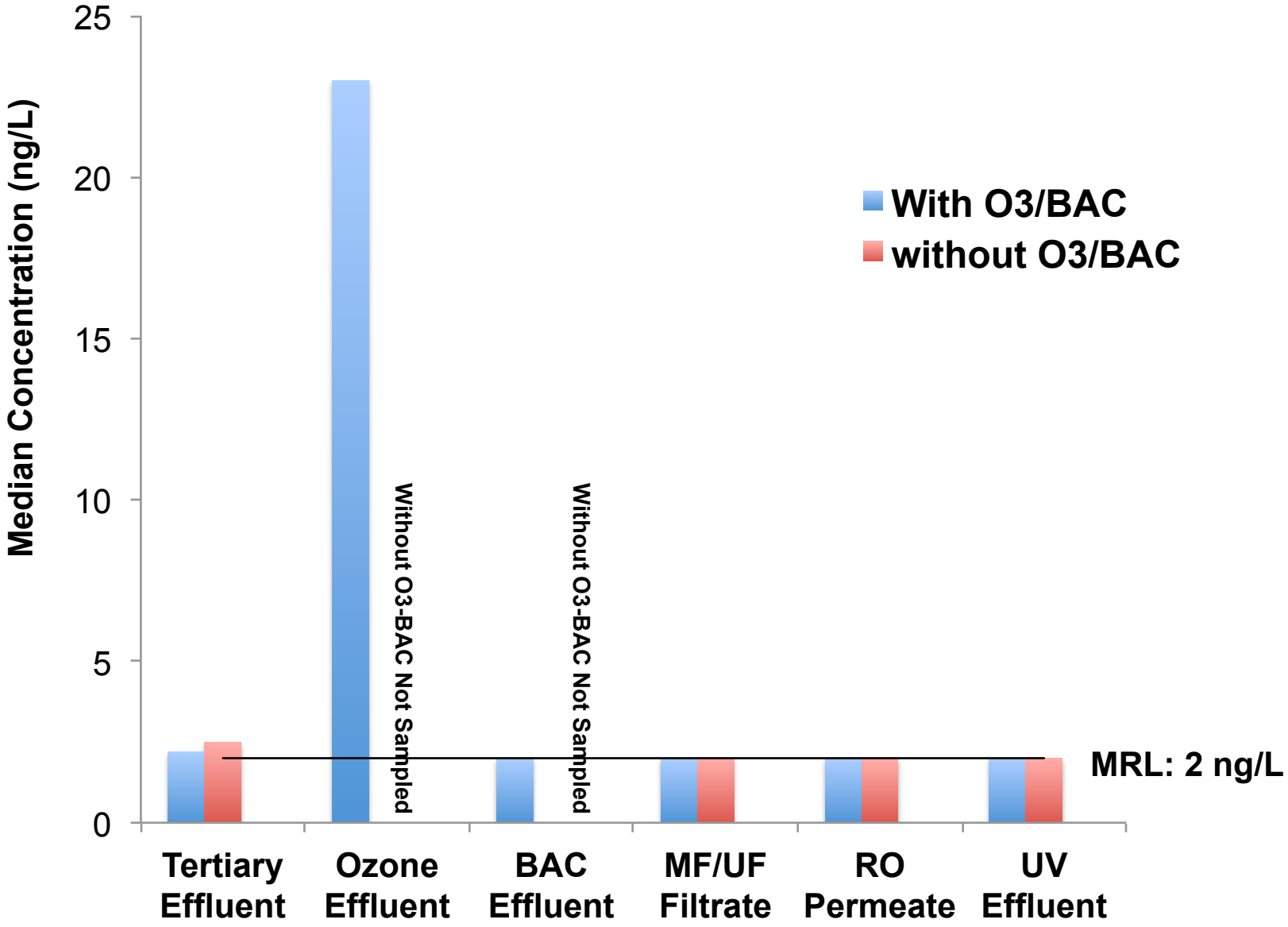
Tertiary Effluent	RO Feed	RO Permeate	RO Concentrate
			

- RO concentrate shows less fluorescence than the feed water (tertiary effluent) and contains **40% less TOC**

Reduction in Feed TOC Benefits Product Water Quality

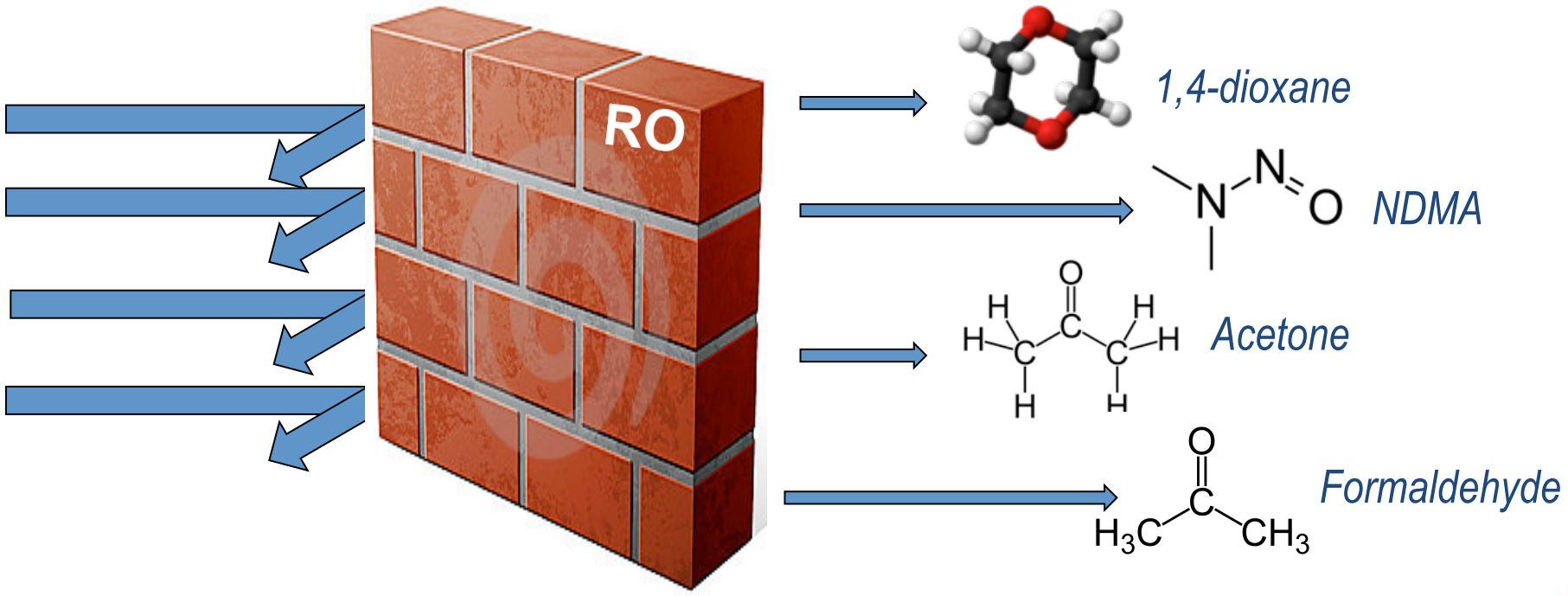


NDMA Formation and Removal

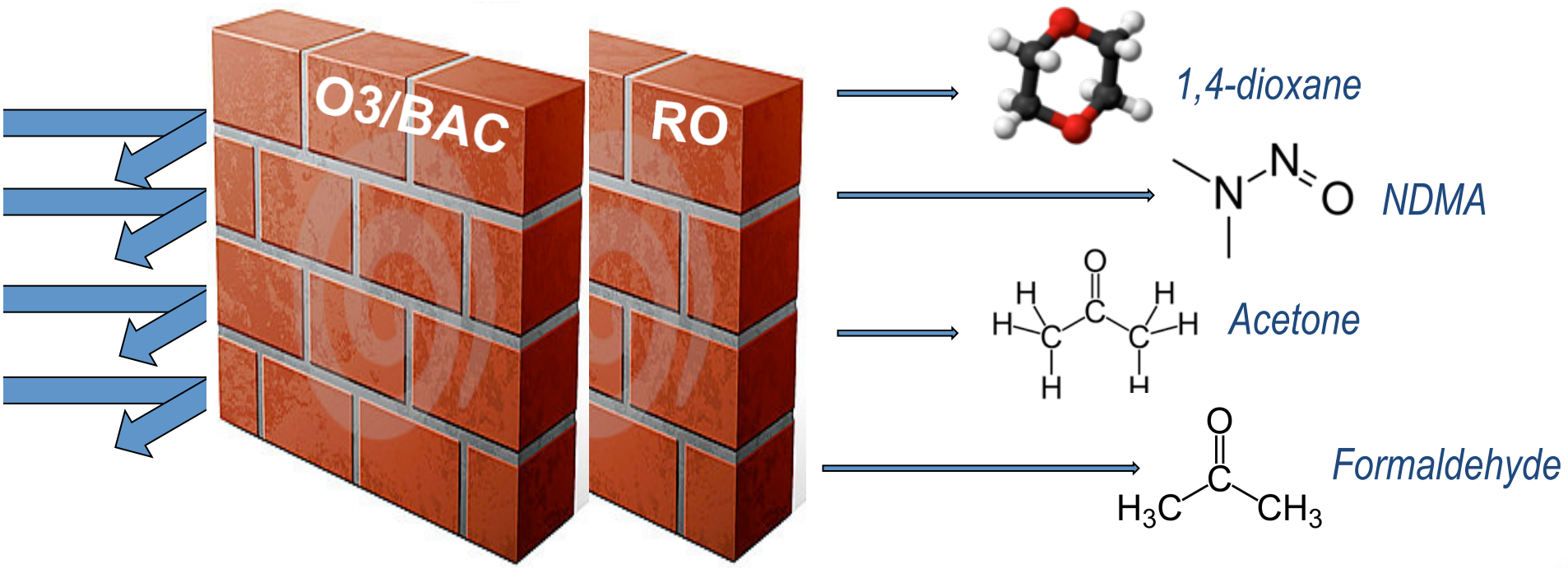


CHALLENGE TESTS

Chemical Challenge Test



Chemical Challenge Test



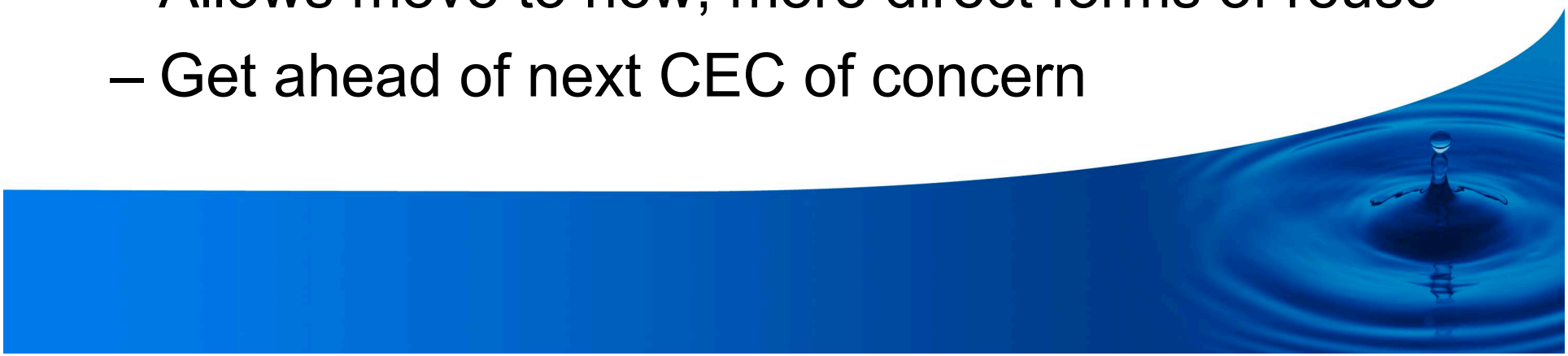
Chemical Challenge Test

Testing at Demonstration Facility on September 18, 2015

NWRI Expert Panel Meeting

Conclusions

- On-going research looking at CEC control for many forms of potable reuse
- History has shown importance of robustness
- Including more robustness into potable reuse trains has great potential:
  - Increase quality and capacity of SAT
  - Allows move to new, more direct forms of reuse
  - Get ahead of next CEC of concern



Research Needs

- Resilience – how to respond to failures in CEC protection
- Surrogates for UV/AOP performance
  - Chloramine destruction
  - UVA destruction

QUESTIONS?