State of the Science: Surface Water Augmentation and CECs

Presentation to the CEC Science Advisory Panel for Recycled Water

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July 19, 2017

Providing Safe Drinking Water

- Treatment Technologies

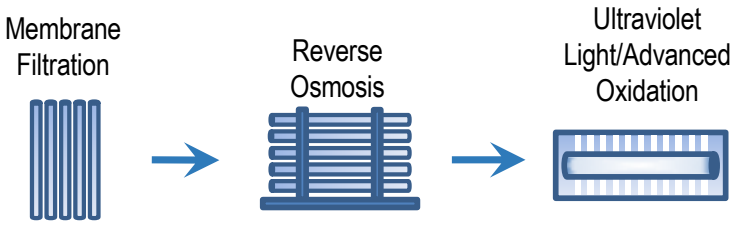
- Natural Environment

Groundwater Recharge

- How do we provide safe drinking water?

Groundwater Recharge

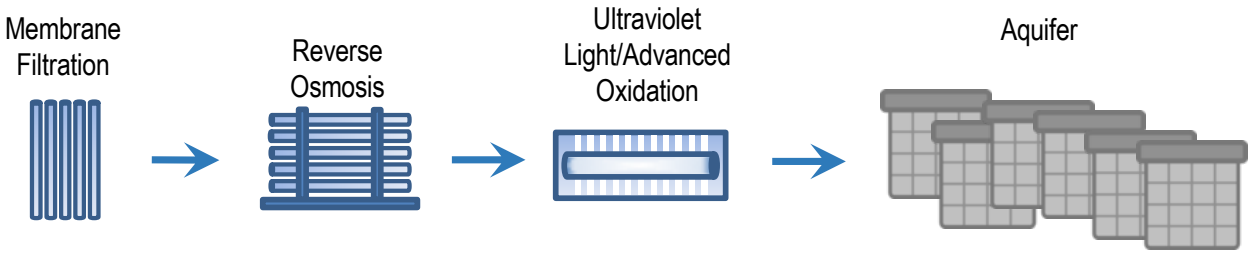
Standard Full Advanced Treatment



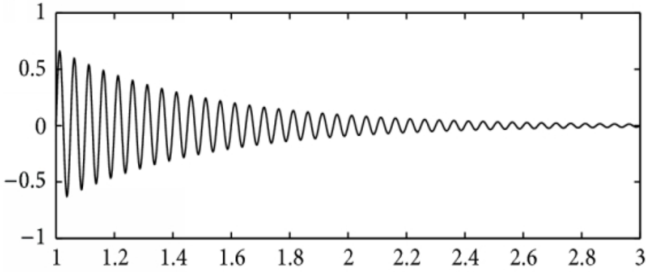
- Treatment Technologies

Groundwater Recharge

Standard Full Advanced Treatment + Retention Time

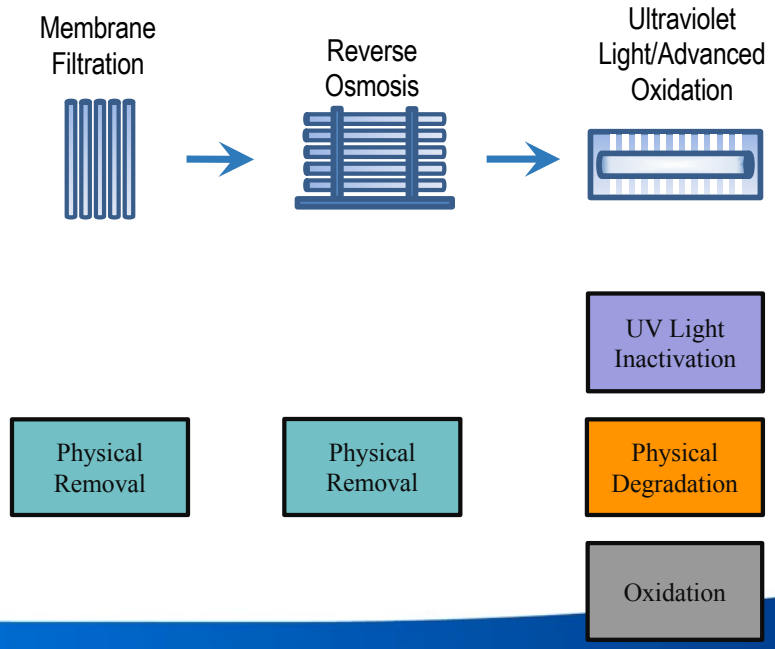


- Treatment Technologies
  - Time 
  - Attenuation (dilution, dispersion, degradation, adsorption, etc.)



Treatment Technologies

- Diversity of removal mechanisms are used to control diversity of chemicals
- Multiple removal mechanisms also proactively mitigate next "unknown"



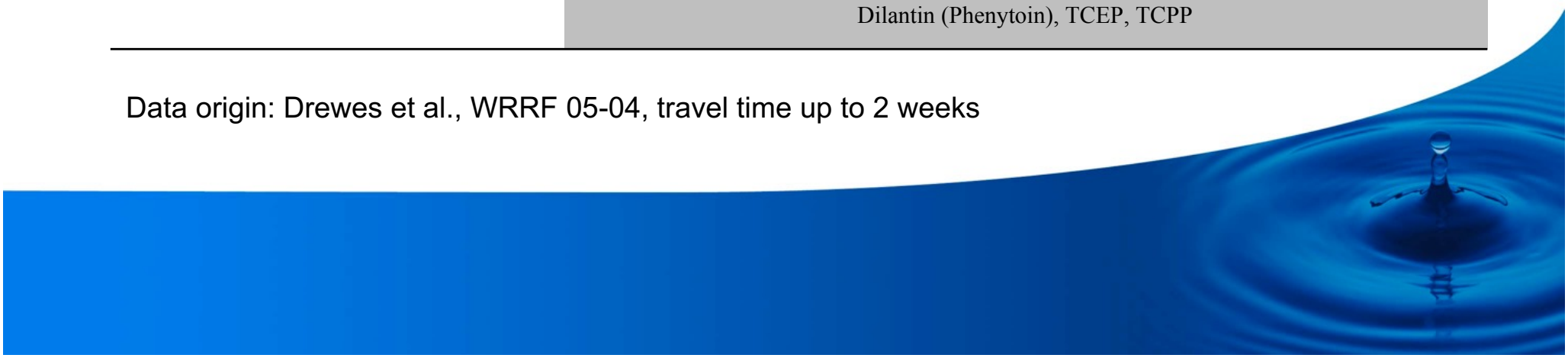
Natural Environment

- Treatment (degradation)
  - Soil Aquifer Treatment
  - Continuing to investigate the treatment benefits of groundwater recharge
- Time
  - Response Time

CEC Removal by SAT

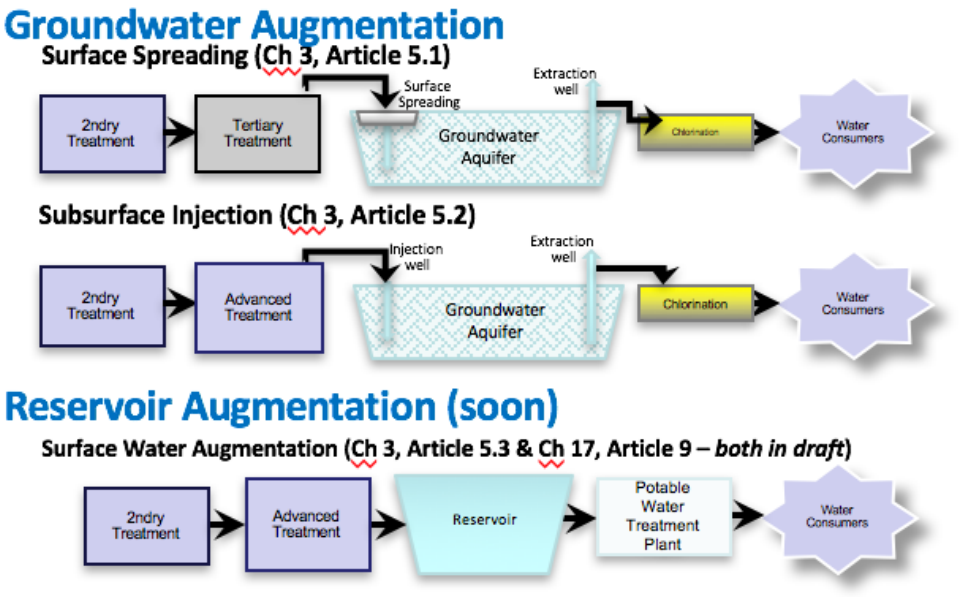
Excellent Removal (>90%)	Fair Removal (90 to 50%)	Poor Removal (50 to <25%)
Atenolol, Atorvastin, BHA, Caffeine, Dioctyl phthalate, Enalapril, Fluoxetine, Galaxolide, Nonylphenol, Norfluoxetine, Salicylic acid, Simvastatin hydroxy acid, Trimethoprim		Carbamazepine, Primidone, TDCPP
Benzophenone, Ibuprofen, DEET, EDTA, Iopromide, Meprobamate, Sulfamethoxazole		
Diclofenac, Naproxen, Gemfibrozil, Octylphenol, Tonalide, Triclosan		
	Dilantin (Phenytoin), TCEP, TCPP	

Data origin: Drewes et al., WRRF 05-04, travel time up to 2 weeks



Surface Water Augmentation

- What changes as we move from groundwater recharge to surface water augmentation?



Surface Water Augmentation

- What changes as we move from groundwater recharge to surface water augmentation?

Loss of Natural Environment Treatment

California Toxics Rule Compliance

Nutrient Limits

Surface Water Augmentation

- What changes as we move from groundwater recharge to surface water augmentation?

Loss of Natural Environment Treatment

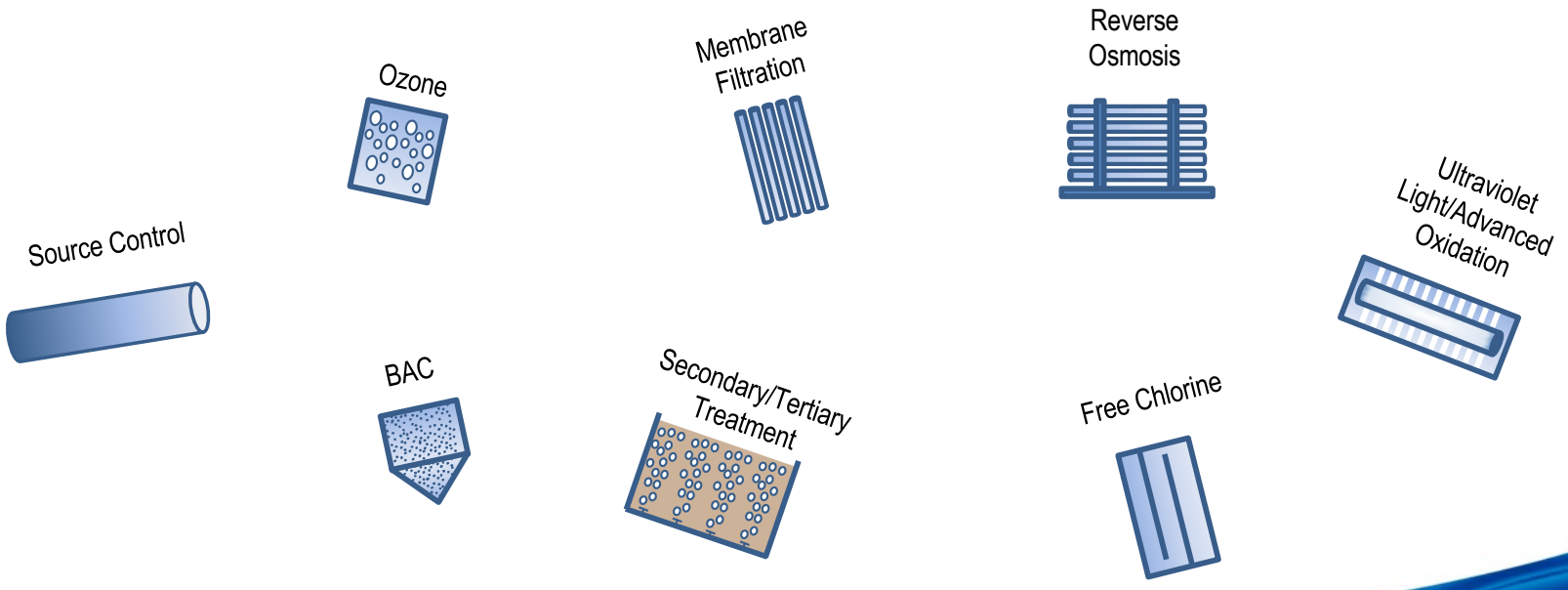
California Toxics Rule Compliance

Nutrient Limits

But…no loss in treatment technologies

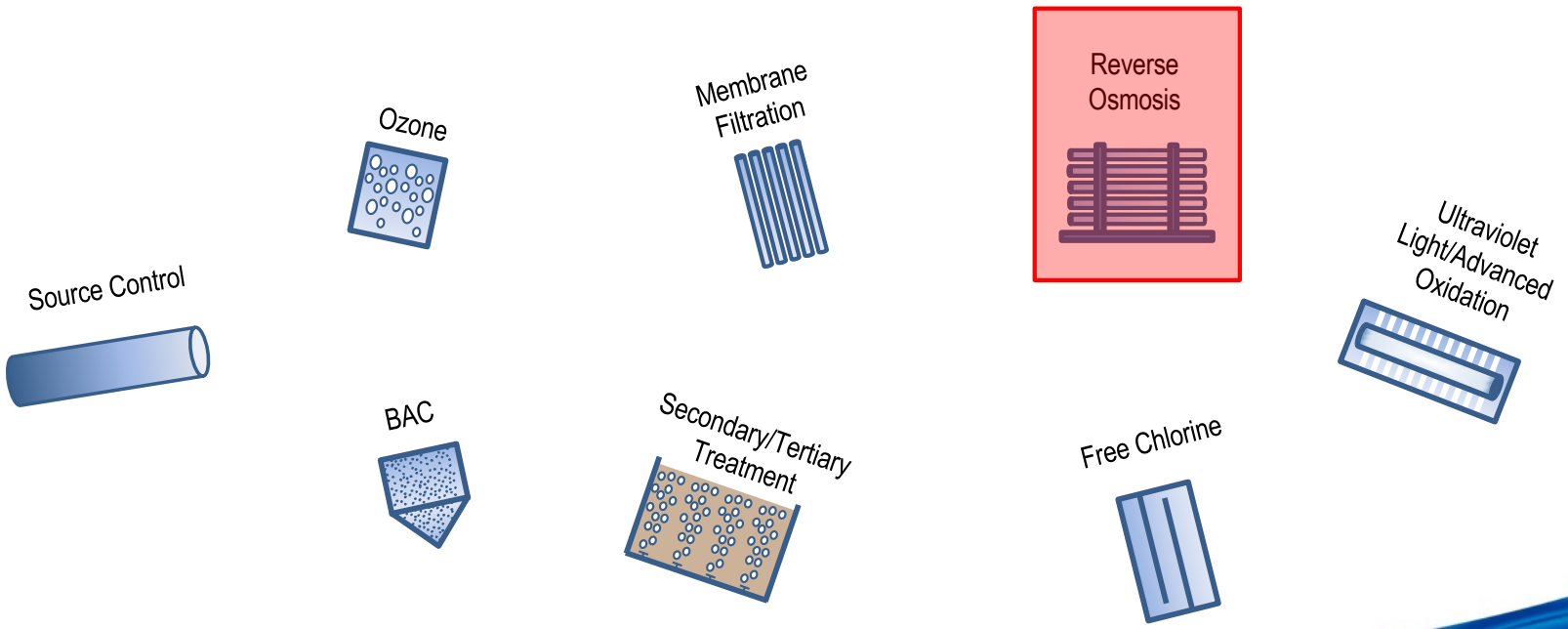
Surface Water Augmentation

- Many treatment technologies available…

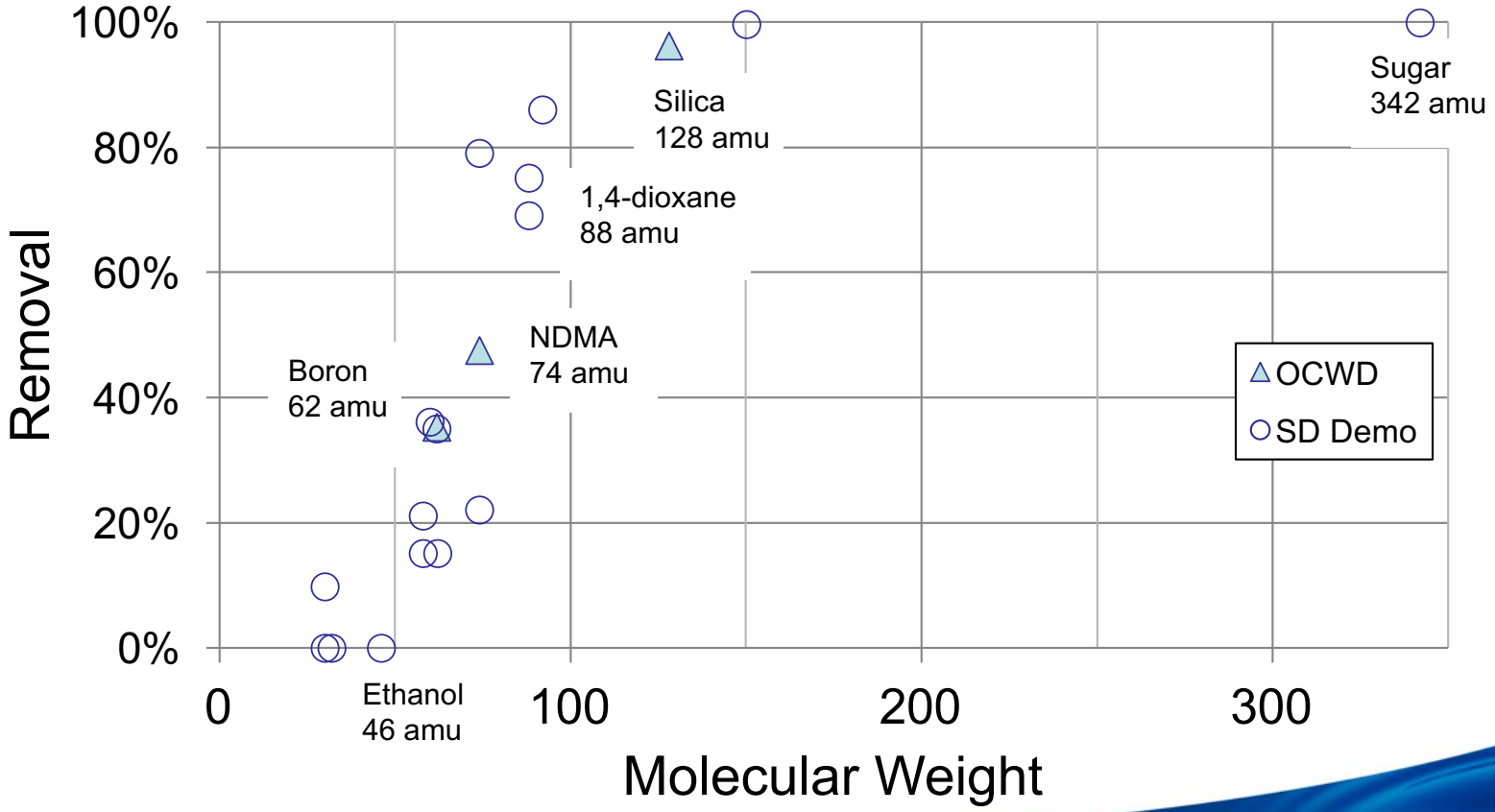


Surface Water Augmentation

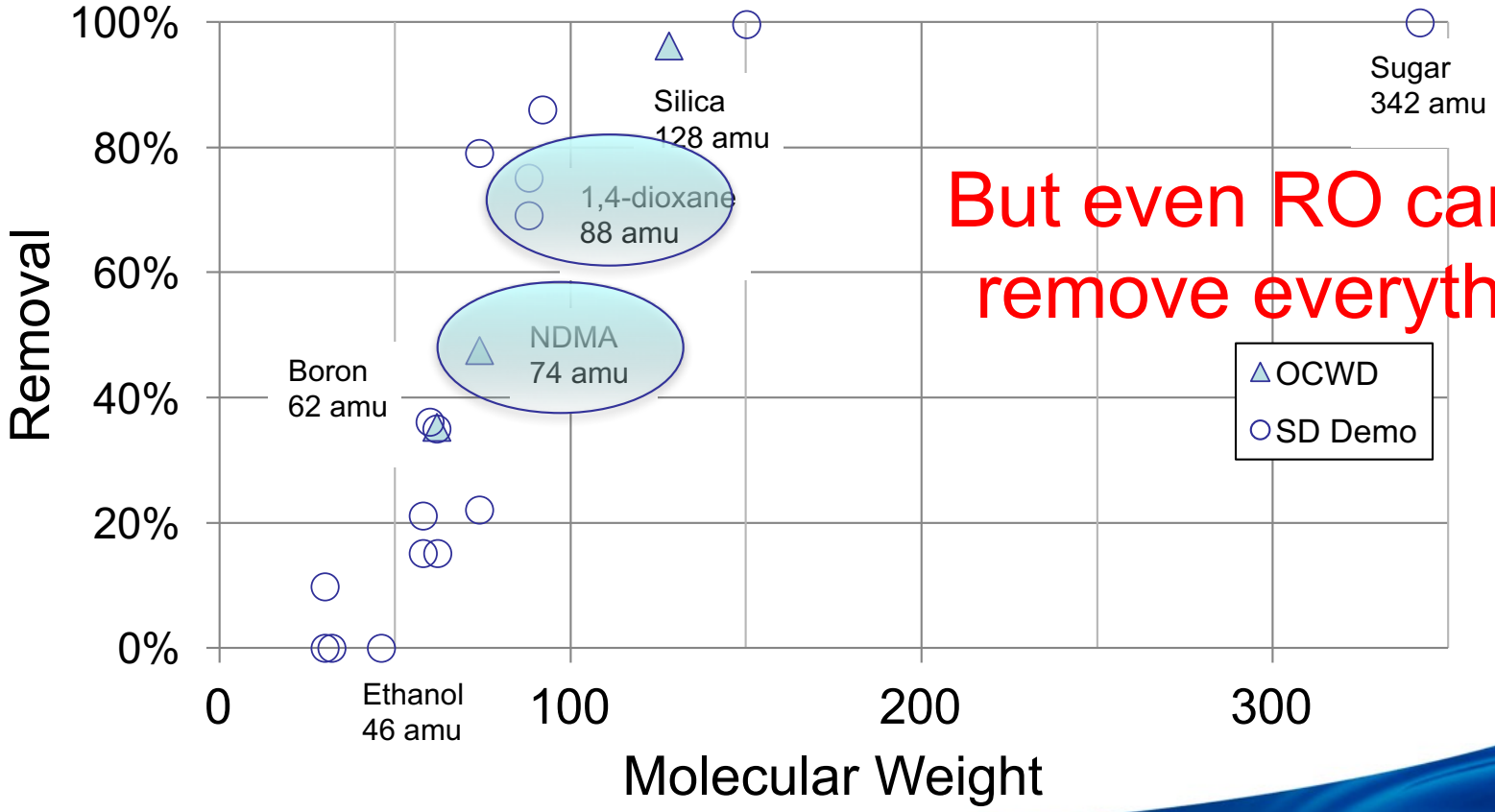
- But RO is by far the most important when considering chemical contaminants



Removal of Uncharged Compounds

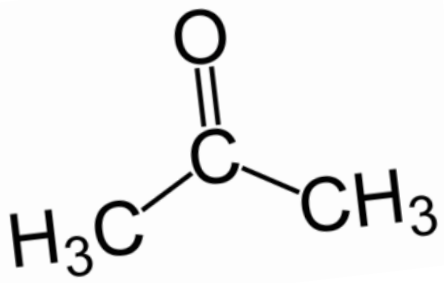


Removal of Uncharged Compounds

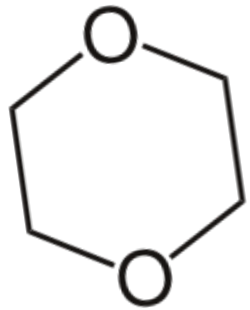


But even RO cannot remove everything

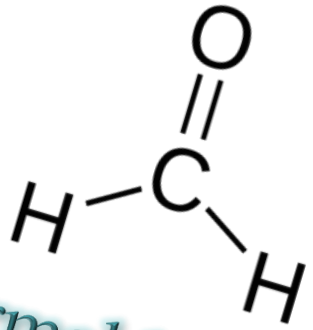
Compounds Can Get Through Reverse Osmosis



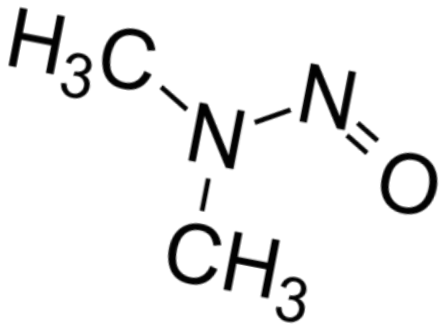
Acetone



1,4 - dioxane

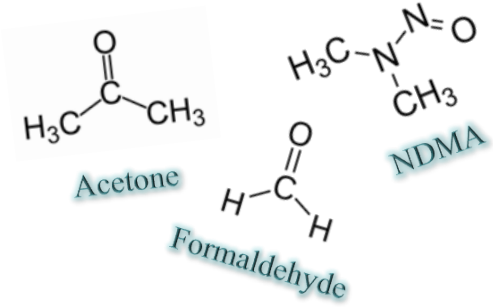


Formaldehyde

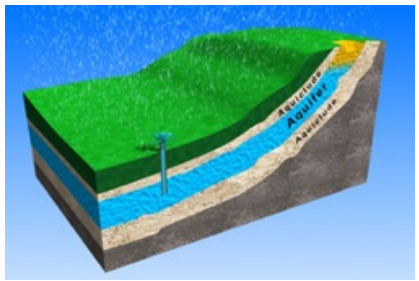


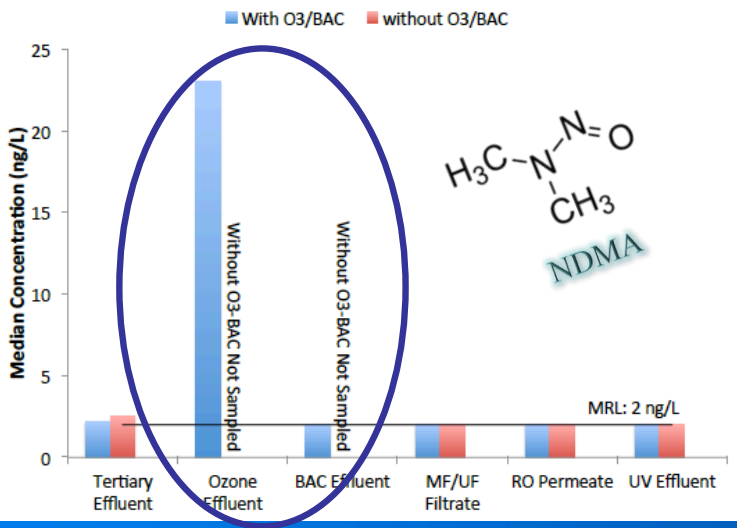
NDMA

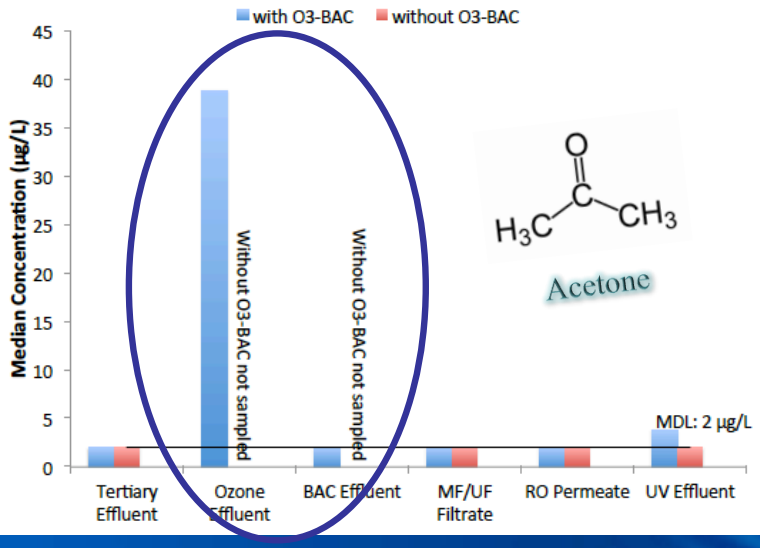
Groundwater Recharge vs. Surface Water Augmentation

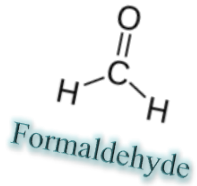


Well removed through **biodegradation** that occurs in the aquifer





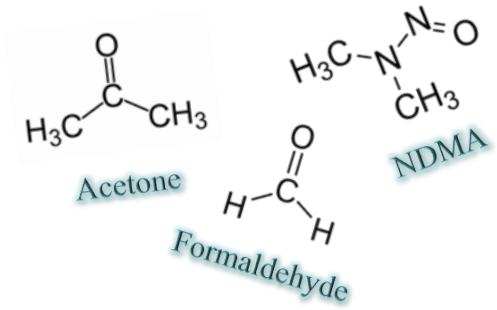




Ozone Effluent: 100µg/L
BAC Effluent: 5.9 µg/L

San Diego Demonstration Facility Data

Groundwater Recharge vs. Surface Water Augmentation



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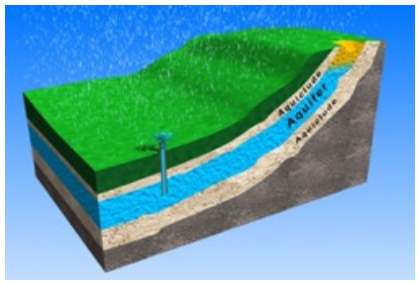
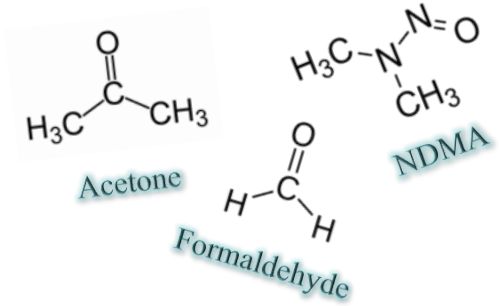
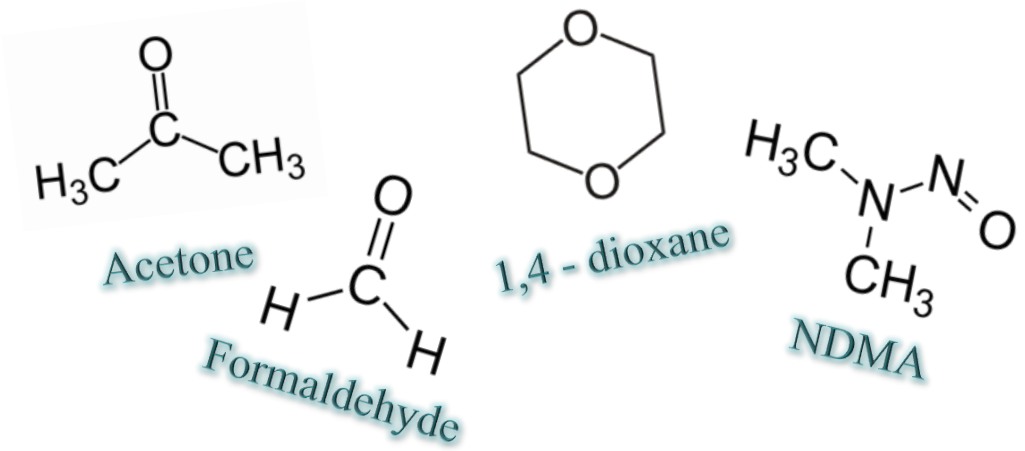




???

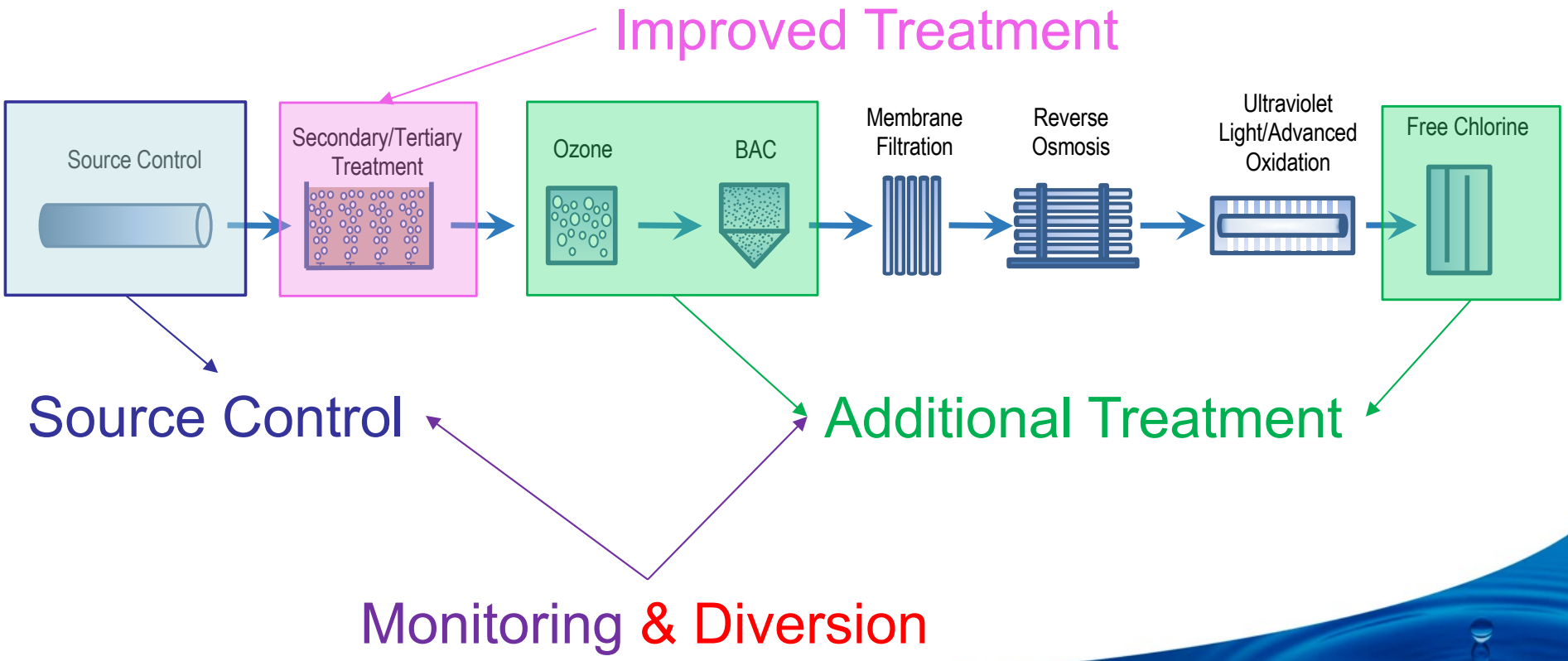
Surface Water Augmentation

How do we ensure we remove and control these compounds?



Tools for SWA

- We have tools at our disposal



Additional Challenges for SWA

- California Toxics Rule
  - NDMA
    - DDW Notification Level: 10 ng/L
    - **CTR Limit: 0.69 ng/L**
- Nutrient Requirements
  - Nitrogen requirement for GWR: 10 mg/L
  - **Basin Plan Objectives for Nitrogen: ~1-2 mg/L as N**

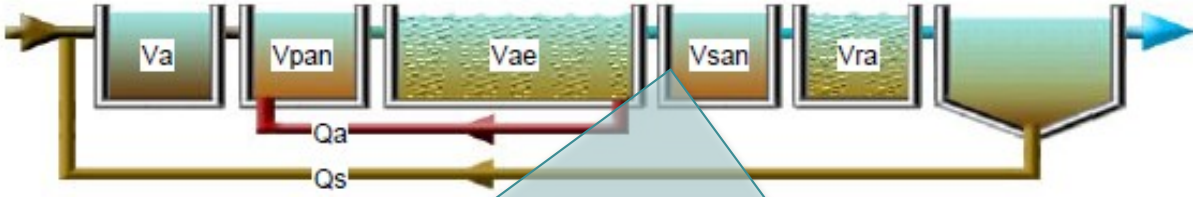
Benefits?
~~Additional Challenges~~ for SWA

- California Toxics Rule
  - NDMA
    - PDWA
- Nut[illegible]rtionments
  - Nitrogen requirement for GWR: 10 mg/L
  - **Basin Plan Objectives for Nitrogen: ~1-2 mg/L as N**

Requires improved secondary treatment to reduce nitrogen levels

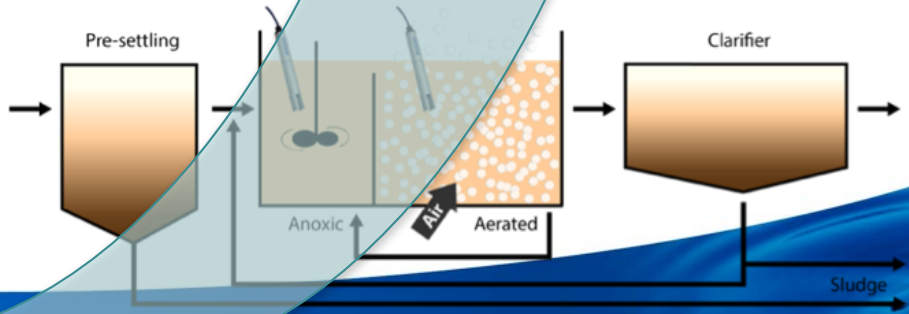
Evolution of Biological Treatment

5-stage Bardenpho



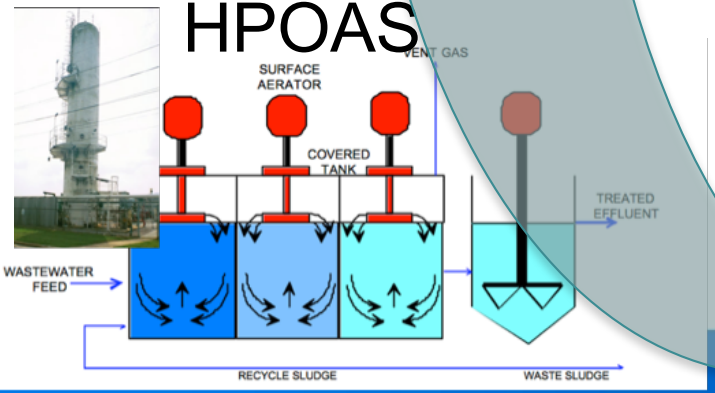
Ca 1980

Modfied Ludzack-Ettinger Process



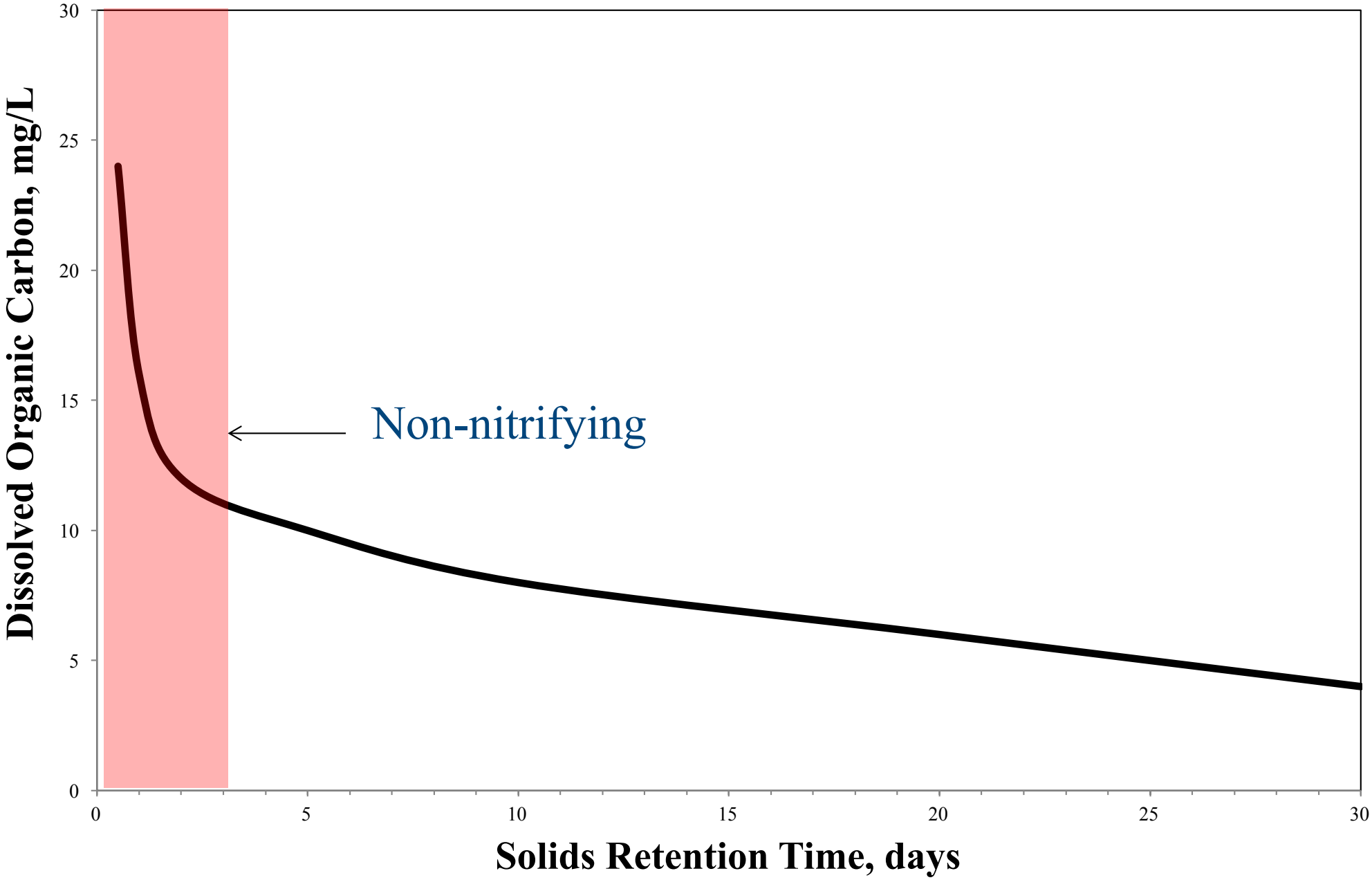
1973

HPOAS

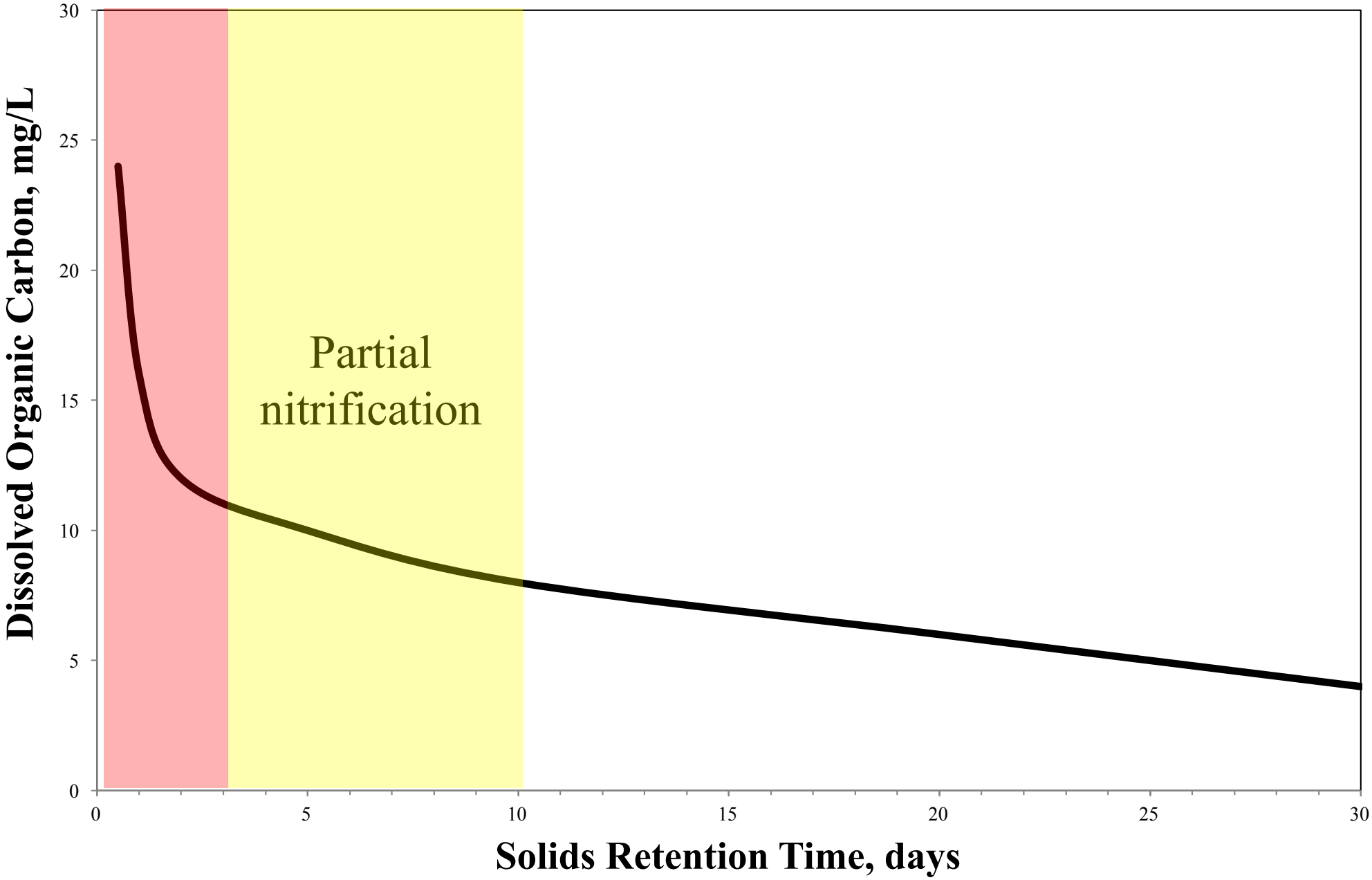


1970

Importance of Solids Retention Time



Importance of Solids Retention Time



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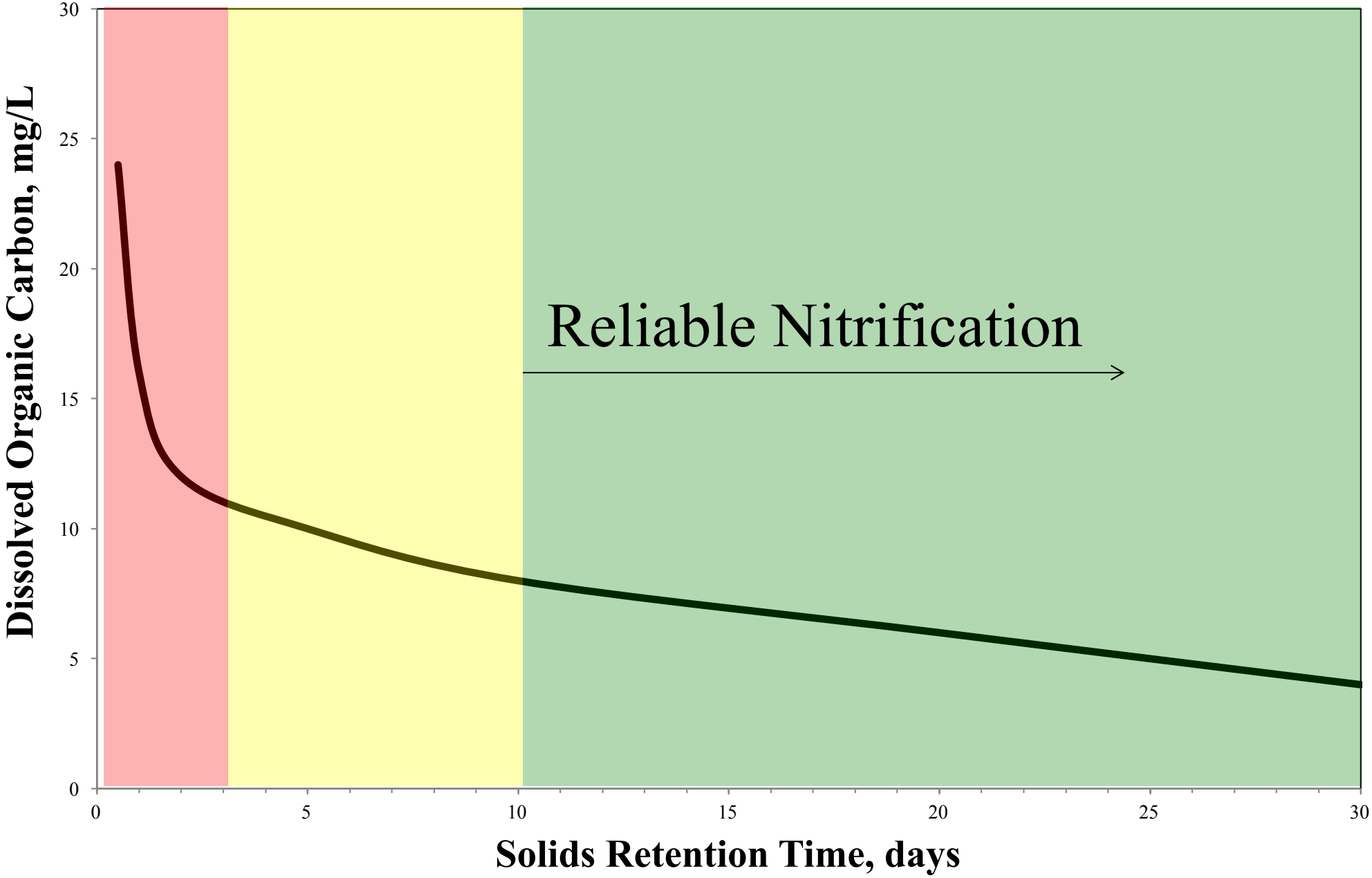

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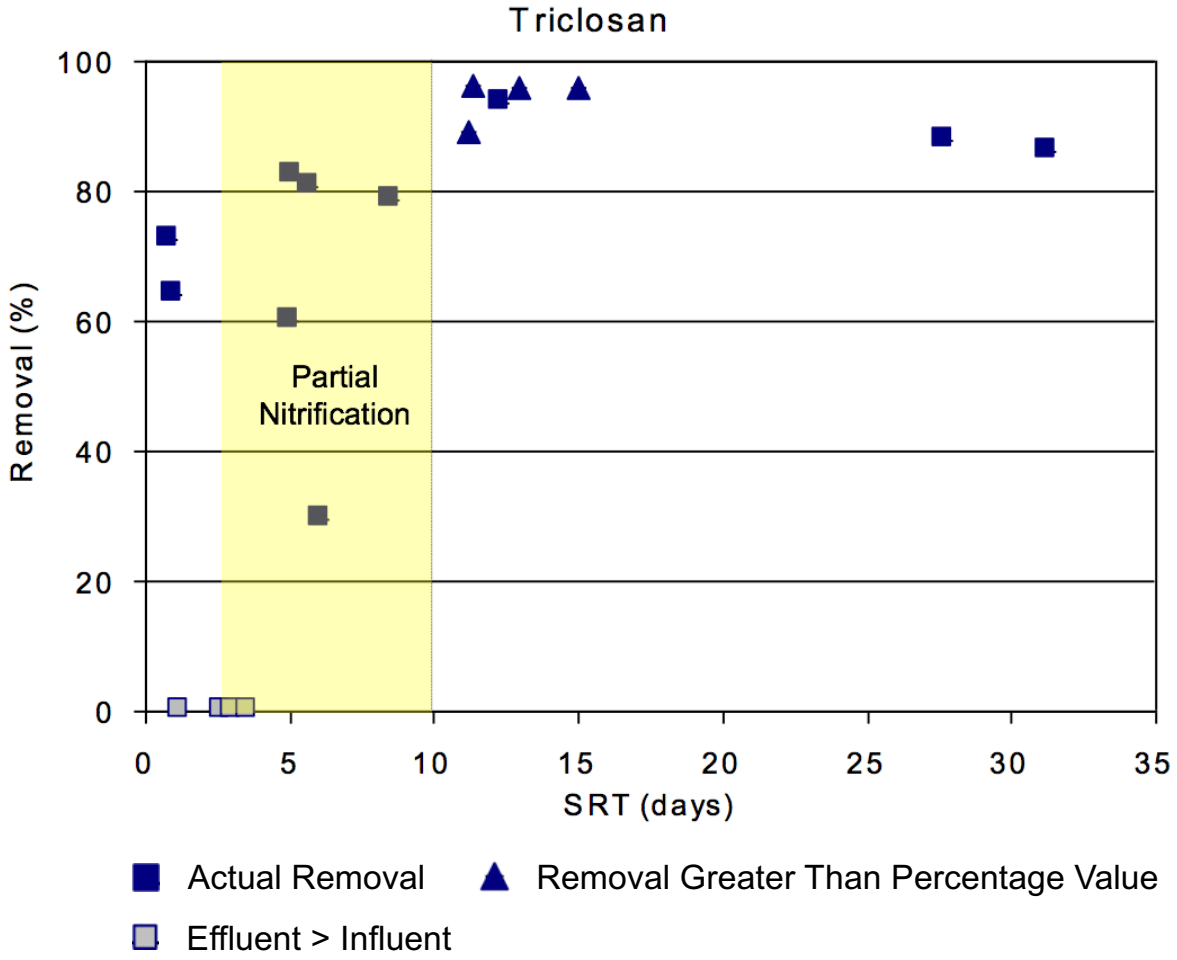
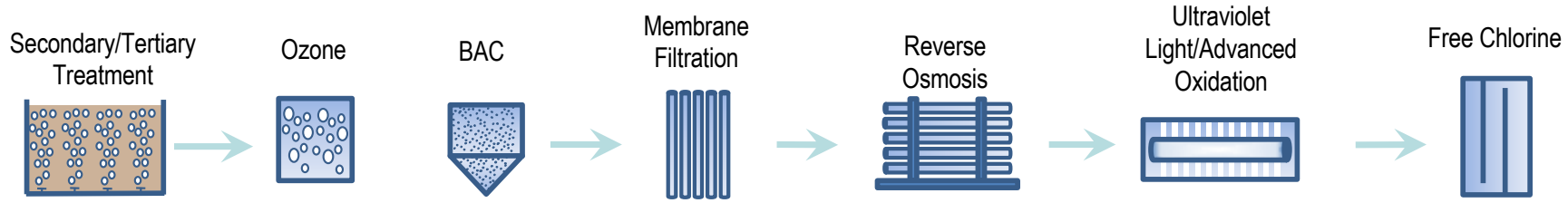


- SRT is also important to CEC removal

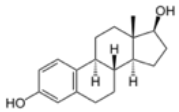
Robust Treatment is Critical for Chemical Control

- No single process effectively controls the wide diversity of chemical contaminants

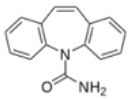


17β-estradiol	Excellent	Excellent	Poor	Excellent	Excellent	Excellent
Carbamazepine	Poor	Excellent	Poor	Excellent	Excellent	Poor
NDMA	Fair	Good	Poor	Fair	Excellent	Poor
1,4-dioxane	Poor	Good	Poor	Good	Good	Poor

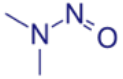
17β-estradiol



Carbamazepine



NDMA



1,4-dioxane

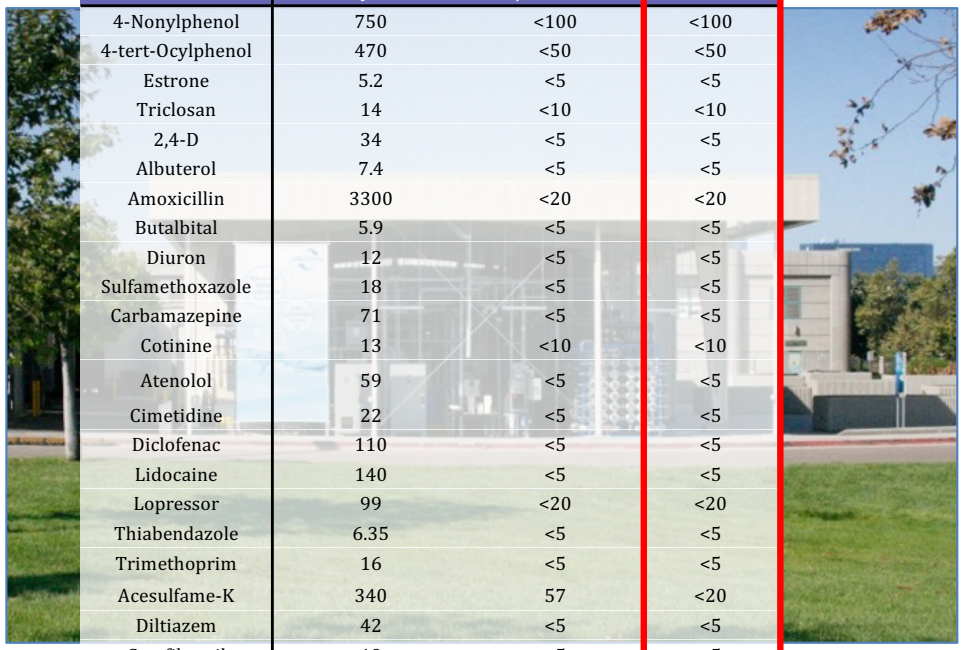
CEC Control at Demonstration Facilities

San Diego Demonstration

Padre Dam Demonstration

CEC Control at Demonstration Facilities

San Diego Demonstration



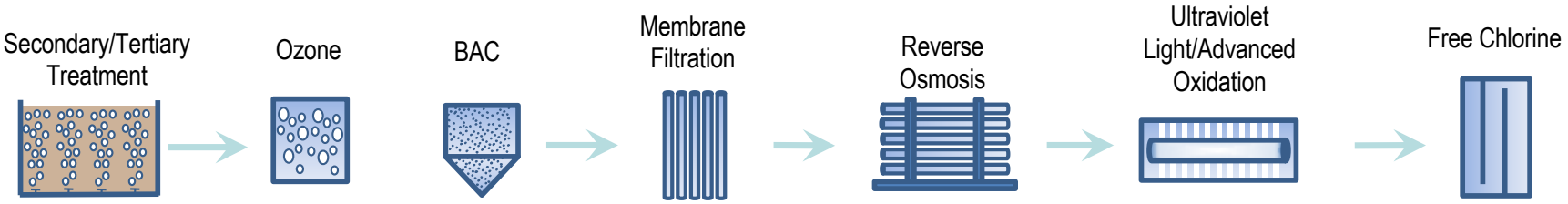
CEC:	Median Concentration (ng/L)		
	Tertiary Effluent	MF/UF Filtrate	UV Effluent
4-Nonylphenol	750	<100	<100
4-tert-Ocylphenol	470	<50	<50
Estrone	5.2	<5	<5
Triclosan	14	<10	<10
2,4-D	34	<5	<5
Albuterol	7.4	<5	<5
Amoxicillin	3300	<20	<20
Butalbital	5.9	<5	<5
Diuron	12	<5	<5
Sulfamethoxazole	18	<5	<5
Carbamazepine	71	<5	<5
Cotinine	13	<10	<10
Atenolol	59	<5	<5
Cimetidine	22	<5	<5
Diclofenac	110	<5	<5
Lidocaine	140	<5	<5
Lopressor	99	<20	<20
Thiabendazole	6.35	<5	<5
Trimethoprim	16	<5	<5
Acesulfame-K	340	57	<20
Diltiazem	42	<5	<5
Gemfibrozil	19	<5	<5
DEET	19	<10	<10
Dilantin	35	<20	<20
Carisoprodol	42	<5	<5
Erythromycin	35	<10	<10
Iohexal	3300	470	<10
Meprobamate	30	<5	<5
Sucralose	16000	4000	<100
TCEP	170	15	<10
TCPP	1100	<100	<100
TDCPP	310	<100	<100

Padre Dam Demonstration

CEC:	Maximum Concentration (ng/L)		
	Secondary Effluent	RO Effluent	UV/AOP Effluent
Atenolol	540	7.8	ND
Carbamazepine	280	<5	ND
Dilantin (phenytoin)	ND	ND	ND
Meprobamate	290	<5	ND
Primidone	190	ND	ND
Perchlorate	400	< 50	230
PFOA	7.2	ND	< 2.5
PFOS	4.6	ND	ND
17α-Ethinyl estradiol	ND	ND	ND
17β-estradiol	0.58	< 0.4	ND
Equilin	ND	ND	ND
Estriol	ND	< 8	ND
Estrone	5.8	ND	ND
NDMA	16	17	ND
Caffeine	ND	ND	ND
Cotinine	48	19	ND
DEET	510	< 100	ND
Sucralose	48000	< 100	180
TCEP	540	< 10	ND
Triclosan	40	ND	ND

Robust Treatment is Critical for Chemical Control

- No single process effectively controls the wide diversity of chemical contaminants



17β-estradiol	Excellent	Excellent	Poor	Excellent	Excellent	Excellent
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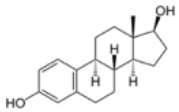
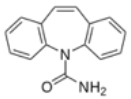
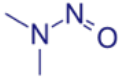
17β-estradiol



Carbamazepine



NDMA

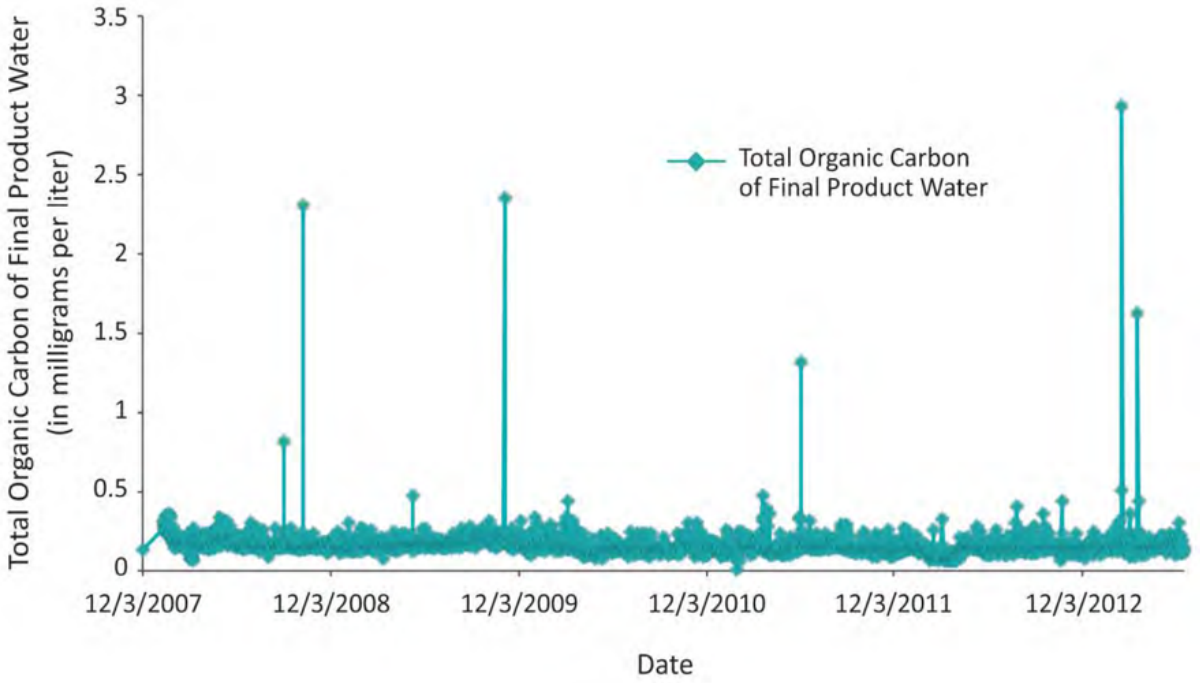


1,4-dioxane

Should not rely solely on treatment technologies…

Additional Monitoring

Five year record of TOC in Final Product Water at OCWD Groundwater Replenishment System

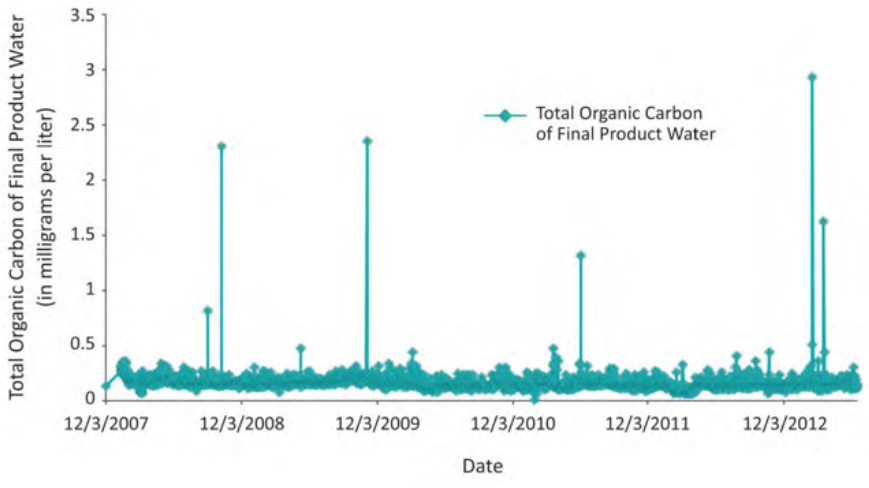


Olivieri, et. al (2016) Evaluation of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse. NWRI (ed), California State Water Resources Control Board, Fountain Valley, CA.

Additional Monitoring

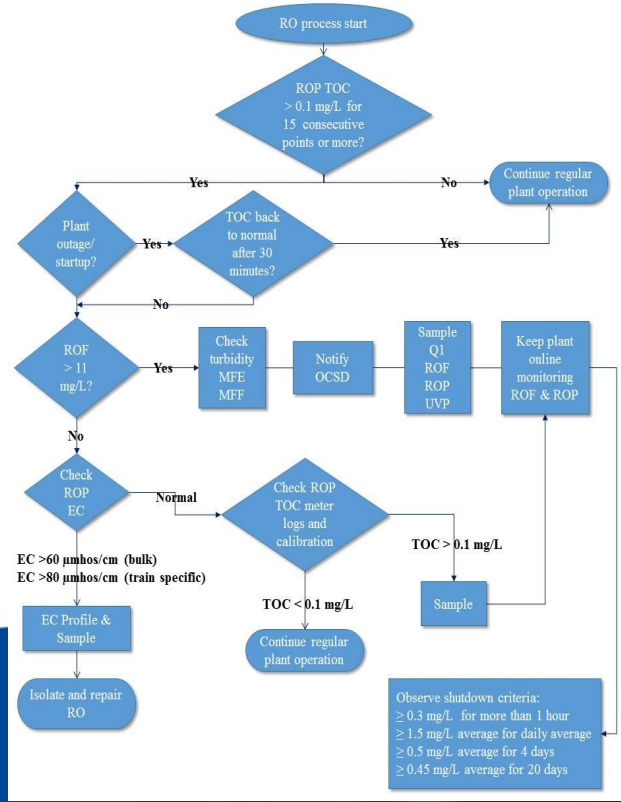
Standard Operating Procedure for TOC Spikes

TOC Excursions



SOP for TOC Spikes

Appendix D: TOC Decision Chart



Source Control

Tougher penalties for dumping of waste water: PUB

Today 28 Dec 2012 Woo Sian Boon woosianboon@mediacorp.com.sg

SINGAPORE — Fines for the dumping of waste water containing chemicals into public sewers will be tripled to S$15,000, while offenders could also be jailed for up to three months.

These are the tougher penalties national water agency PUB will introduce, as 11 factories were caught illegally dumping waste water containing high levels of Volatile Organic Compounds (VOCs) into the sewerage system. Seven offenders were brought to court, while the remaining four had their offences compounded with a fine.

The number of offenders caught this year has surpassed the total number of illegal dumping cases in the last two years. There were seven cases last year, up from two in 2010.

The PUB installed 40 sensors in industrial sites to monitor concentration levels of chemicals discharged into the sewerage system.

VOCs such as paints, methane chloride are commonly present in waste discharges, known as trade effluent, from electroplating, pharmaceutical, printing and food businesses, trades and industries.

Mr Idaly Mamat, Senior Engineer of PUB's Water Reclamation (Network) Department, said: "As some VOCs are toxic and flammable, the discharge of trade effluent containing high concentration of such VOCs into the public sewer poses fire and safety hazards to workers or operators working in the public sewerage system.

"It can also affect the treatment process at water reclamation plants, and subsequently, impact the production of NEWater or industrial water."

Waste water containing levels of these compounds should be collected by licensed toxic industrial waste collectors for offsite treatment and disposal.

The PUB will be amending the Sewerage and Drainage (Trade Effluent Regulations) to effect the stricter penalties. The amendment will kick in by next year.

To further monitor the quality of waste water, the PUB installed 40 VOC sensors last month in industrial sites such as Tuas, Pioneer Sector and Woodlands to monitor the concentration levels of chemicals discharged into the sewerage system.

An SMS alert will be sent to PUB if any illegal discharge is detected, and officers will be deployed on site to trace the discharge.

The sensors also enable PUB to closely monitor 1,783 factories identified as "concerns", out of 4,800 listed in its records,

Since the deployment of the sensors, 20 more cases of waste water with high VOC levels discharged into the public sewerage system were detected, with 18 offenders identified by the PUB. Investigations are ongoing to identify the rest of the culprits.

To further ensure public sewers are free from obstruction — which might lead to overflows and the subsequent pollution of waterways and reservoirs — the PUB has progressively installed some 1,000 sensors since 2010 in manholes island-wide to monitor used water levels.

"Before we had these water-level sensors, we had to depend on public feedback to notify us on water overflowing from manholes into the surroundings," said Mr Idaly.

"With the sensors, we are able to detect this before it happens, so we can stop a blockage before the water overflows into our canals and waterways. This prevents water pollution and prevents public nuisance as well."

- Singapore example
  - VOC monitoring in sewers
- Develop source control programs

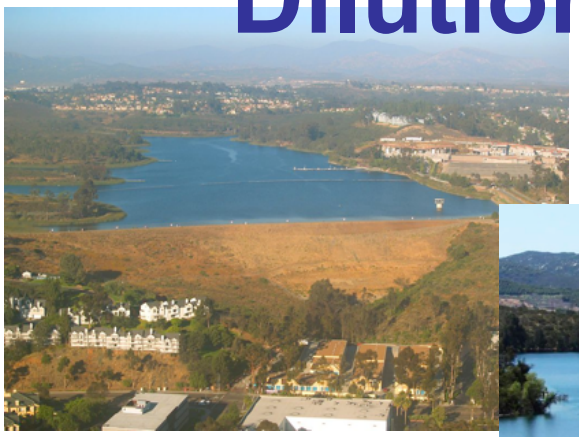
Surface Water Augmentation

- What does the reservoir offer us?

Surface Water Augmentation

- What does the reservoir offer us?

Dilution

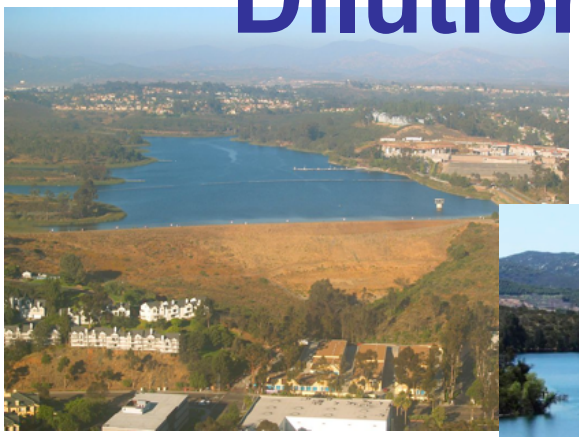


Response Time

Surface Water Augmentation

- What does the reservoir offer us?

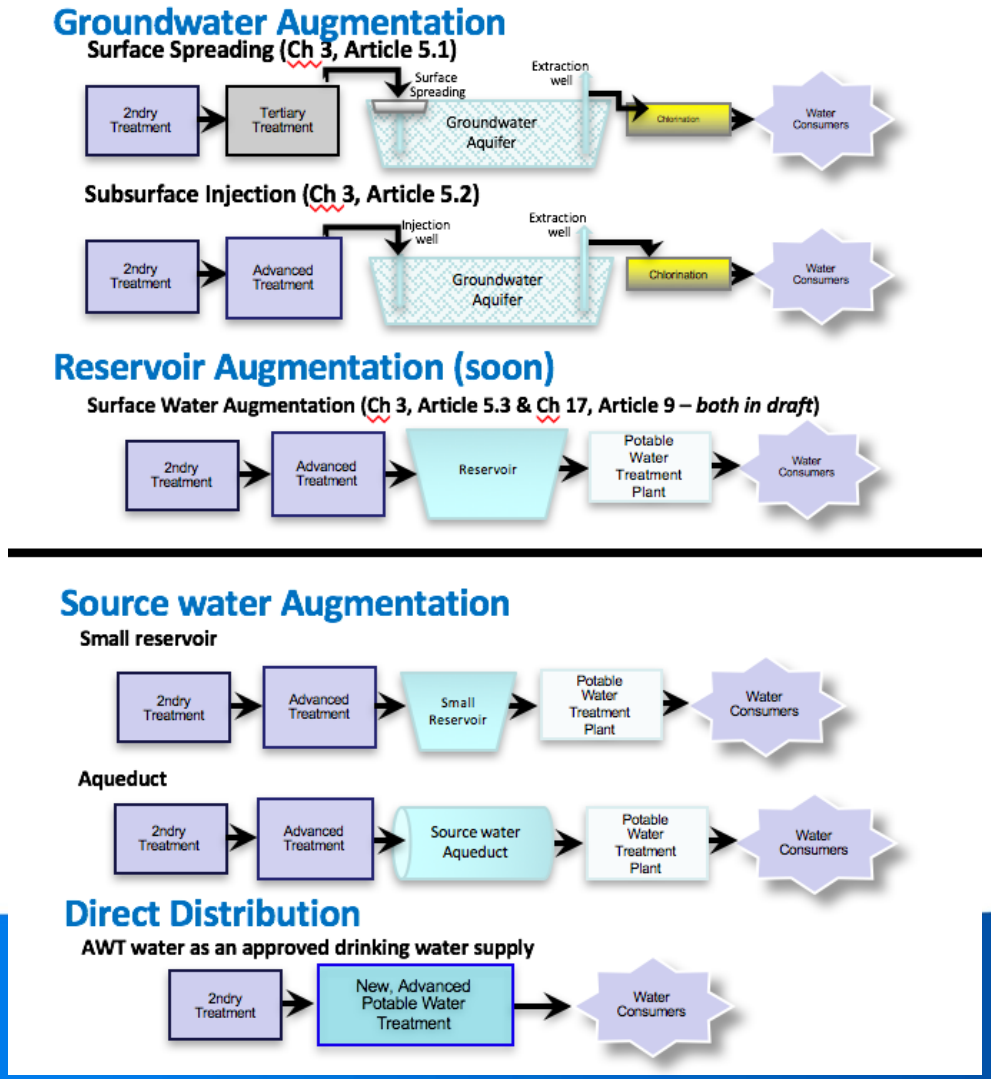
Dilution



Response Time

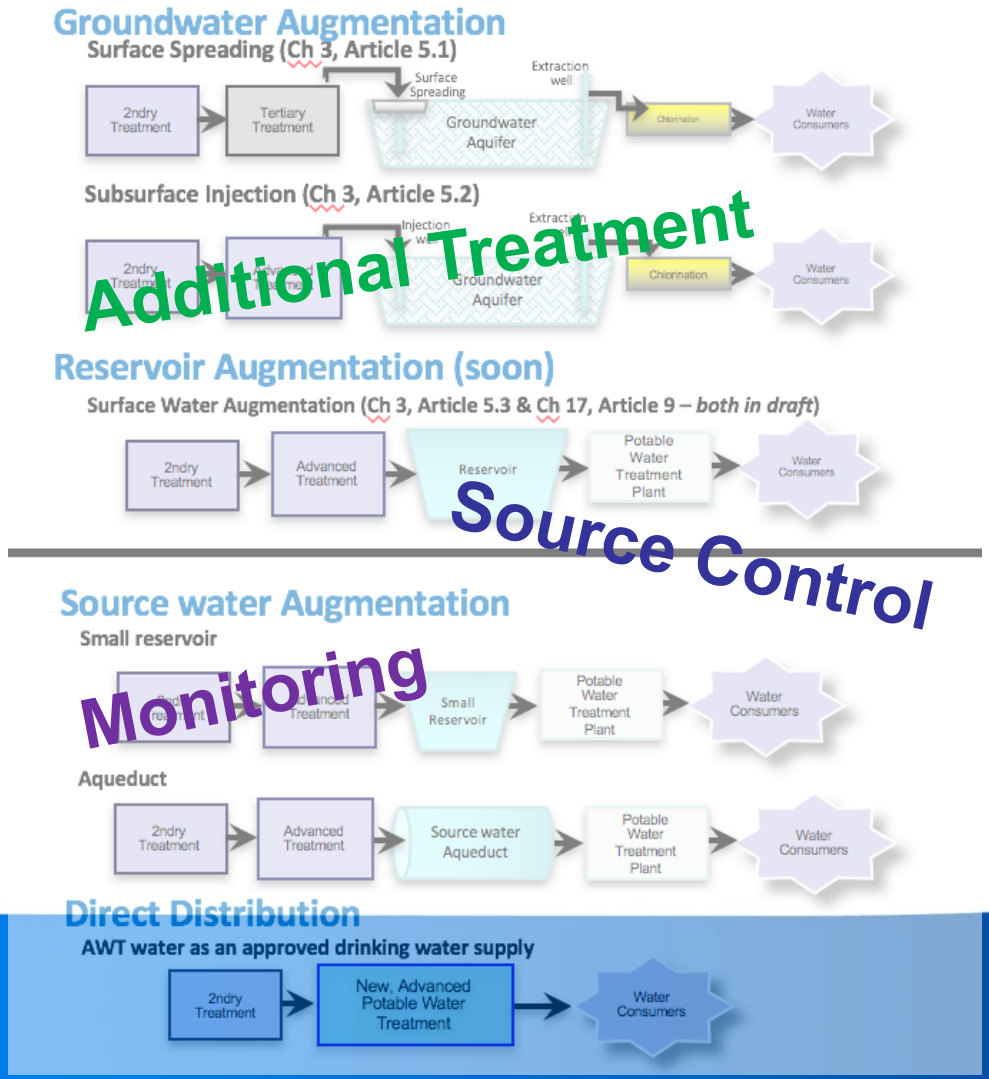
As we move toward direct potable reuse…

Moving to Direct Potable Reuse



- Loss of natural environment
  - Time
  - Treatment

Moving to Direct Potable Reuse



- Loss of natural environment
  - Time
  - Treatment

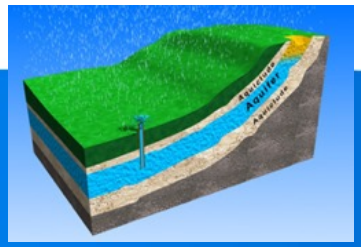
Summary

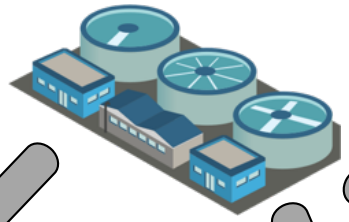
Groundwater Recharge

- Challenges
  - CECs
- Solution
  - Retention time + treatment in ground

Surface Water Augmentation (and Direct Potable Reuse)

- Challenges
  - CECs
  - VOCs
  - California Toxics Rule
  - Nutrient Limits
  - Reduced retention time
  - Loss of natural environmental treatment





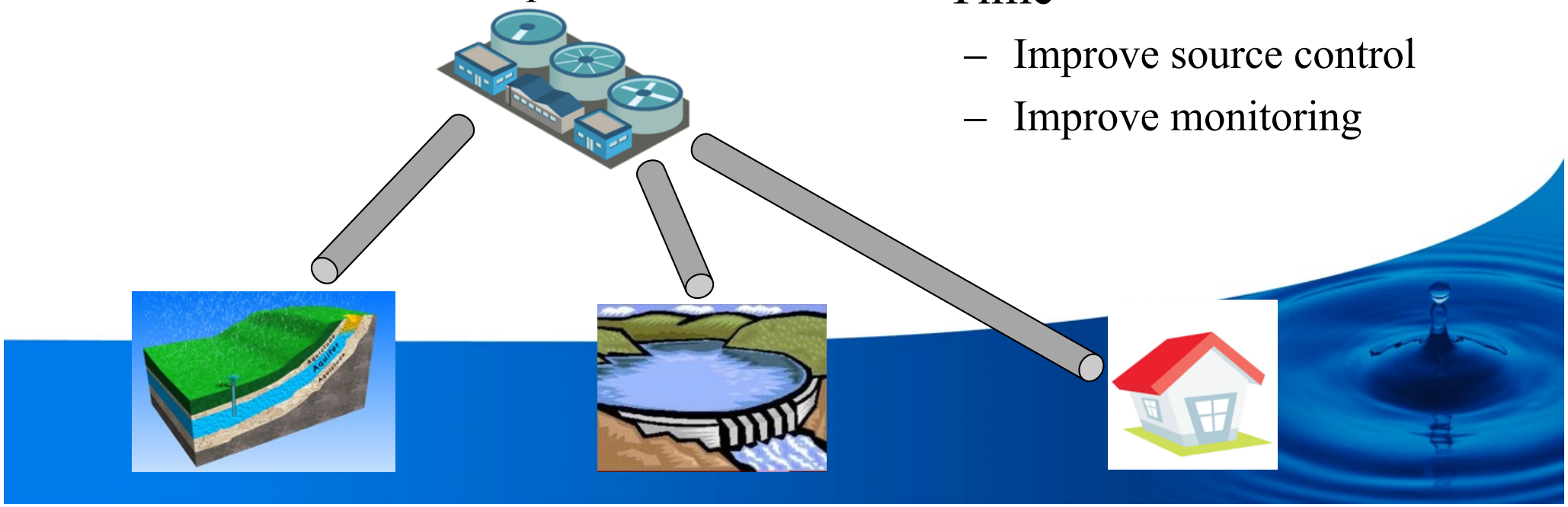
Summary

Groundwater Recharge

- Treatment
  - Full advanced treatment (injection)
  - Disinfected tertiary (spreading)
- Time
  - Retention time in aquifer

Surface Water Augmentation (and Direct Potable Reuse)

- Treatment
  - Full advanced treatment + additional treatment technologies
- Time
  - Improve source control
  - Improve monitoring



Thank you!

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