Treatment Considerations for Surface Water T&O Issues

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Agenda

Sources and causes of taste and odor in surface water

Measurement and monitoring techniques

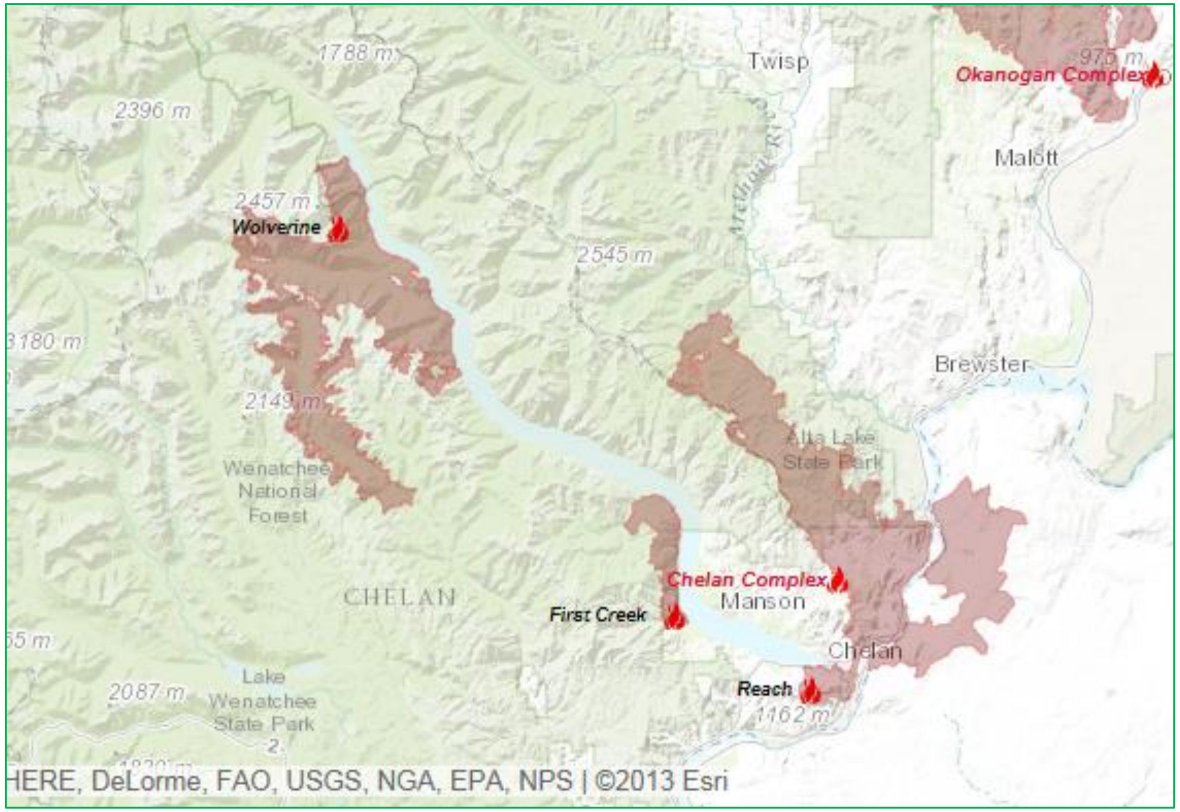
Control and Treatment

- Source Management
- Dissolved Air Flotation
- Biological filtration
- Activated Carbon
- Ozone
- Other oxidation (chlorine dioxide, chlorine, permanganate)
- Advanced Oxidation Process (AOP)

Sources of T&O in Surface Water

Climate change is expected to have many impacts on drinking water supplies

- Stress on water supplies
- Increased frequency of forest fires

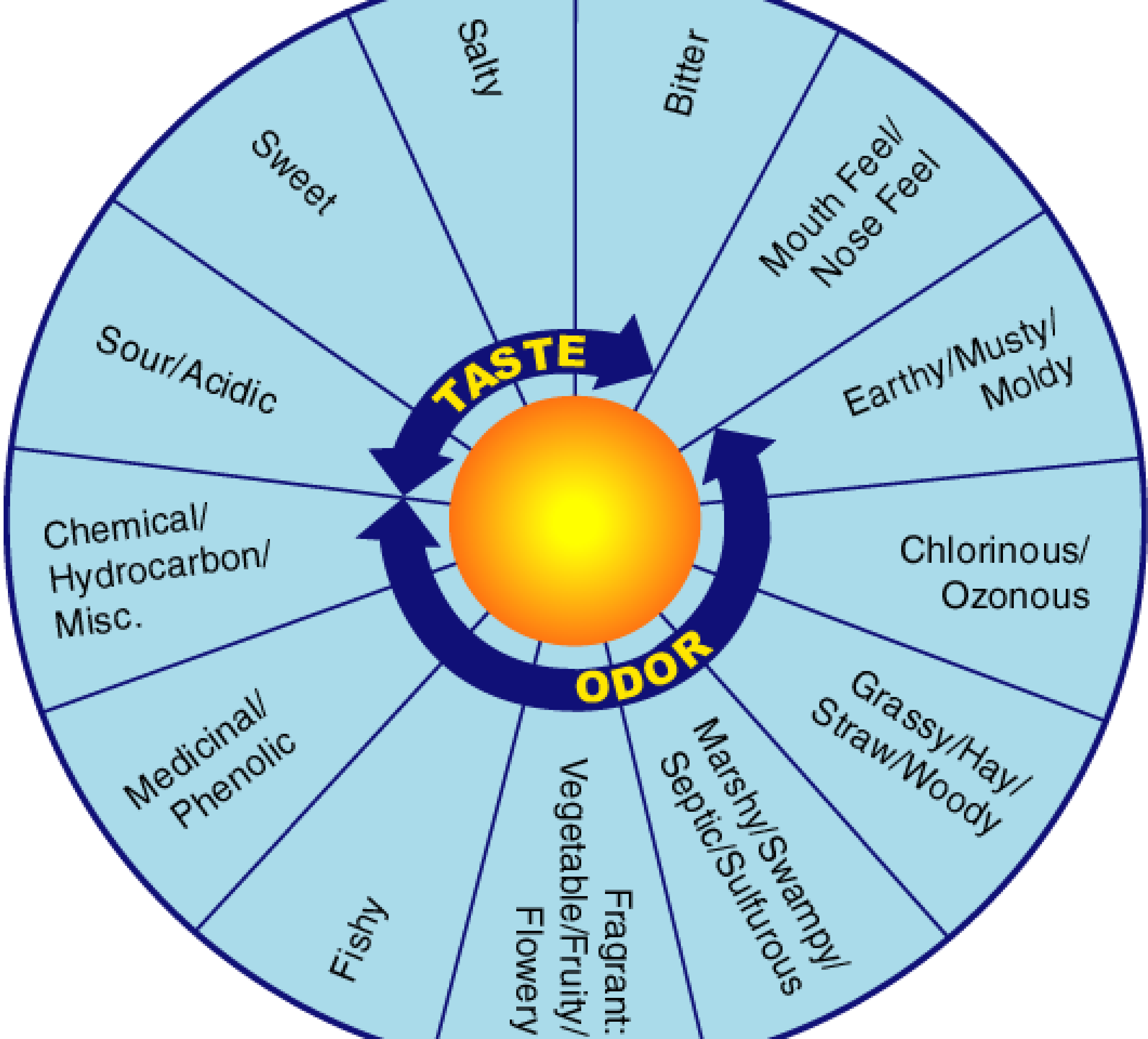


Lake Chelan, WA Forest Fires 2015, Source: NWCC

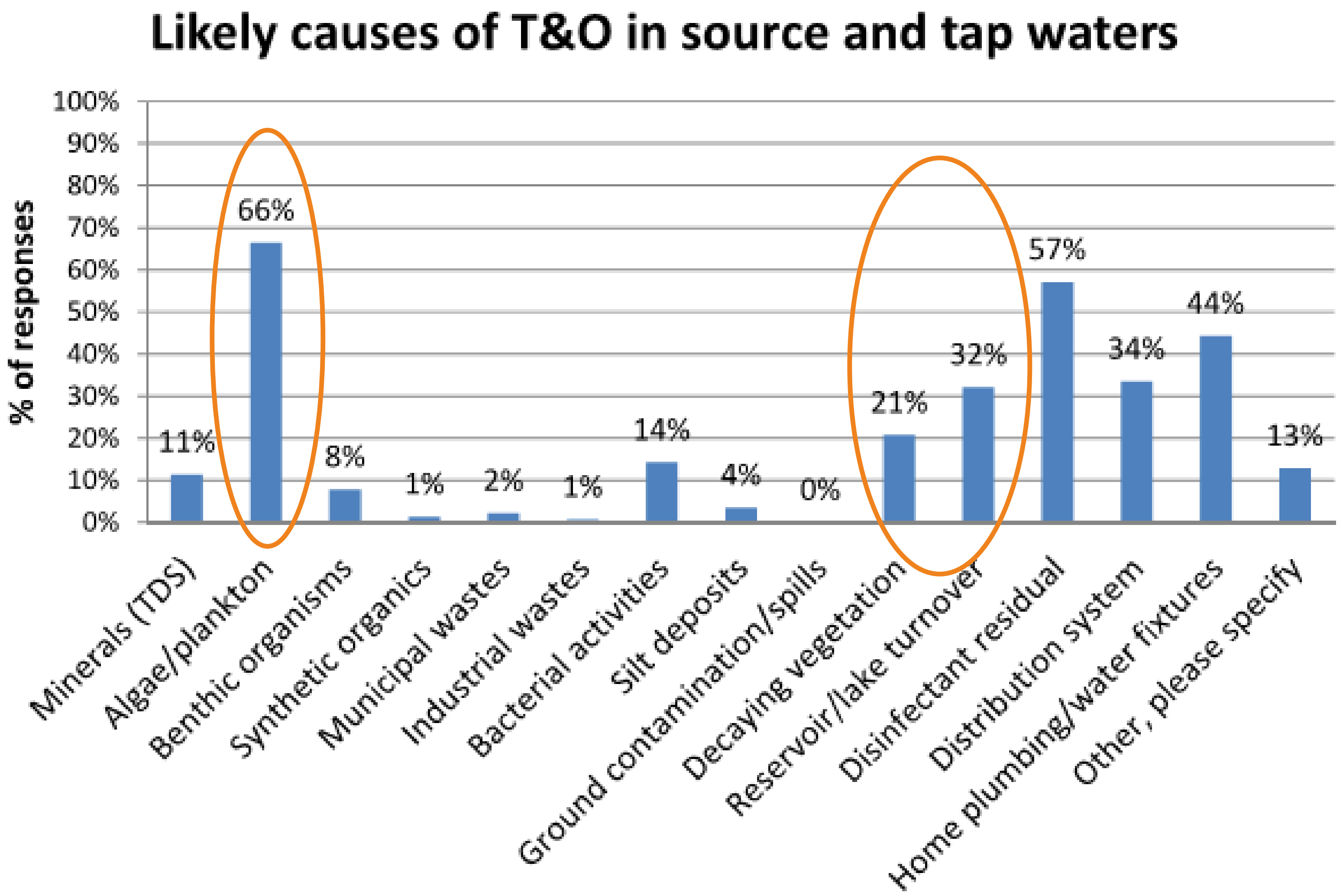
- Increased frequency of heavy rains
- Increased proliferation of algae & algal toxins

Lake Erie Algal Bloom, 2013, Source: NOAA

Types of Taste and Odor Occurrence



Algae presents the greatest source of T&O for surface water



Global Taste and Odor Survey of Water Utilities, AWWA 2012

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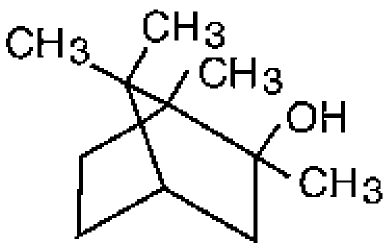
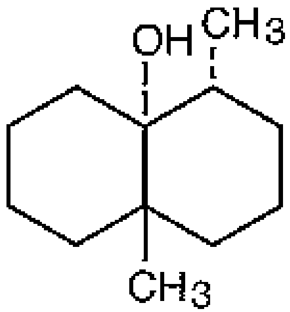
Primary causes of taste and odor in surface water - geosmin and MIB

- Metabolic byproducts of algae
- Geosmin and MIB are most prevalent
- Produce earthy/musty odors not removed during conventional treatment
- **Occurrence** – seasonal (summer and fall)
- **Odor threshold concentration (OTC)** - 2 to 10 ng/L
- For comparison hydrogen sulfide (H_2S) odor threshold - 5,000 ng/L





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Algal metabolites

- Taste & Odor: Geosmin and MIB are most problematic for WTPs
- Can also release toxins
- Produced during growth, within algal cell
- Metabolites can be released from algal cells
  - Death
  - Grazing by zooplankton
  - Signaling in response to environmental factors
  - Cell rupture (lysis) during water treatment

Toledo Free Press photo by Christie Materni

Algae related issues in water treatment plants

- Clogging of intake screens
- Fouling weirs/disruption of settling
- Algal mats
- Filter clogging from algae or extracellular organic matter
- Increased coagulant demand
- Increased chlorine demand
- Increased disinfection by products (DBPs)
- pH fluctuations
- Tastes and odors
- Release of algal toxins from cell lysing

Measurement & Monitoring Techniques

Traditional sensory & chemical evaluation techniques

- Threshold Number (TON)
  - A threshold dilution test

- Flavor Profile Analysis (FPA)
  - Panel of trained analysts evaluates T&O characteristics
  - Standardized qualitative and quantitative T&O characterization (Flavor Rating Scale, Flavor Rating Assessment, Flavor Threshold Test)

- Gas Chromatography (GC)
- New techniques: attribute rating test, difference method, 2-of-5 odor test.

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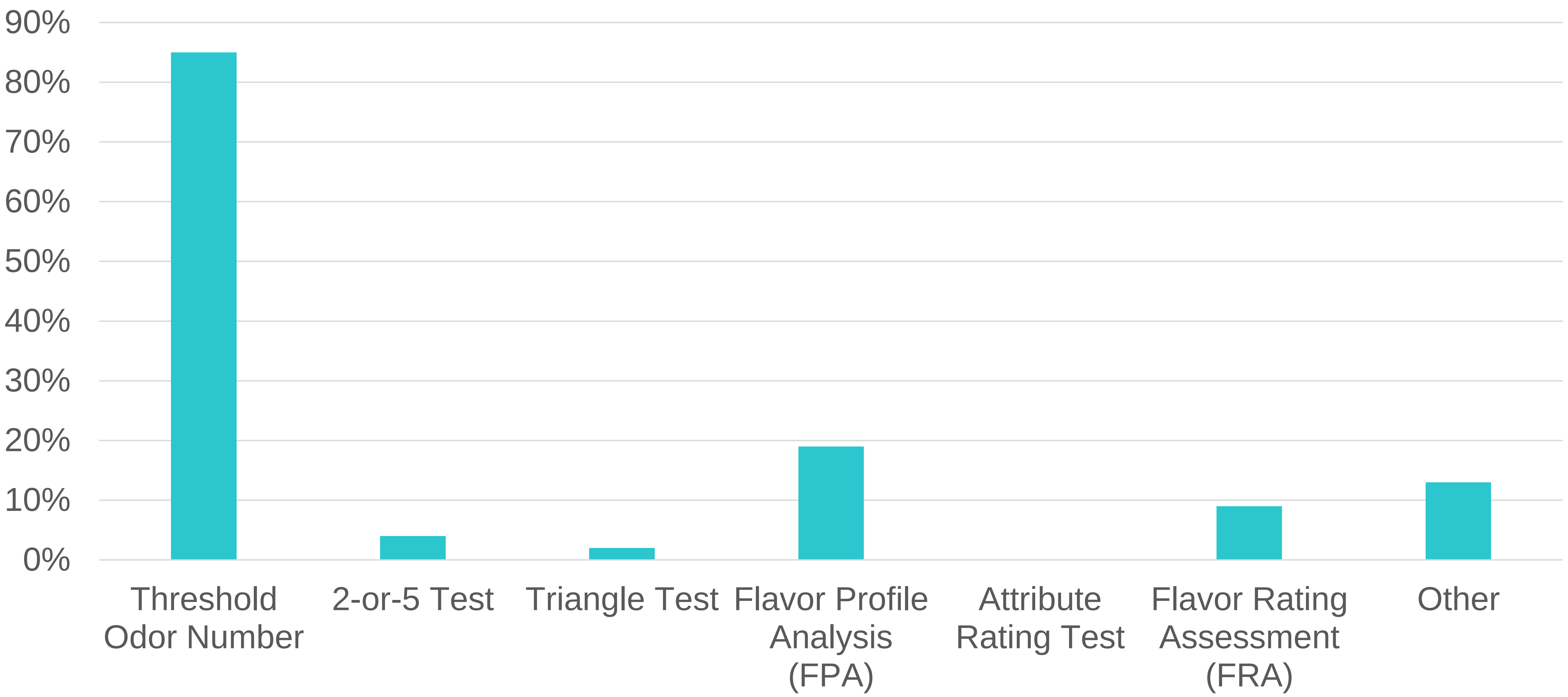
Sensory methods



Global Taste and Odor Survey of Water Utilities, AWWA 2012

Control and Treatment

Treatment selected to remove algae or treat toxins/T&O

Treatment	Removes algae	Addresses toxins and T&O compounds
Source management	☑	
Clarification (DAF, Sedimentation)	☑	
Biological Filtration	☑	☑
Adsorption (PAC or GAC)		☑
Oxidation (chlorine, chlorine dioxide, permanganate, ozone)		☑
Advanced Oxidation (UVAOP or Ozone AOP)		☑

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Source Water Management

Source water management

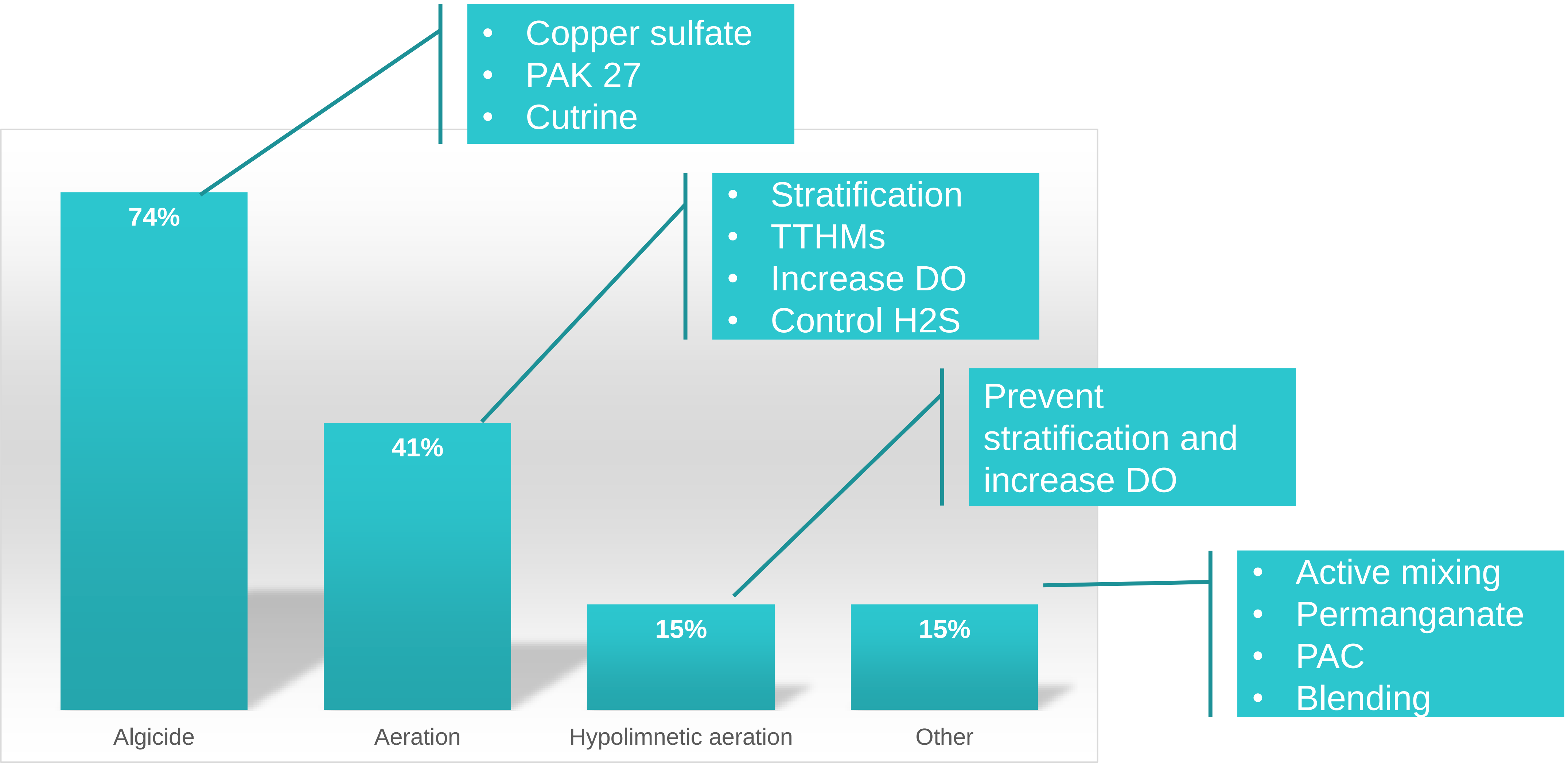
Operational Changes

- Reservoir by-pass
- River bank filtration

Limiting Nutrients - Controlling Phosphorus – In Lake Treatments

- **Hypolimnion Aeration/Oxygenation** – limits P release from Sediment
- **Ferric Coagulation** – difficult to control in anoxic areas
- **Alum** – aluminum toxicity
- **Lime** – May effectively precipitate and control P, doesn’t lyse cells
- **Dredging of sediments** – can be effective longer term
- **Surface Aeration** – mixed results
- **Hypolimnion withdrawal** – removes P from anoxic, no chemicals, requires sufficient new flow input
- **Lake Flushing** – effective if sufficient flow of low P water available
- **Mixing** – increases epilimnion, 80% of volume mixed, high rate of mixing, deep lakes

Preventive methods in use



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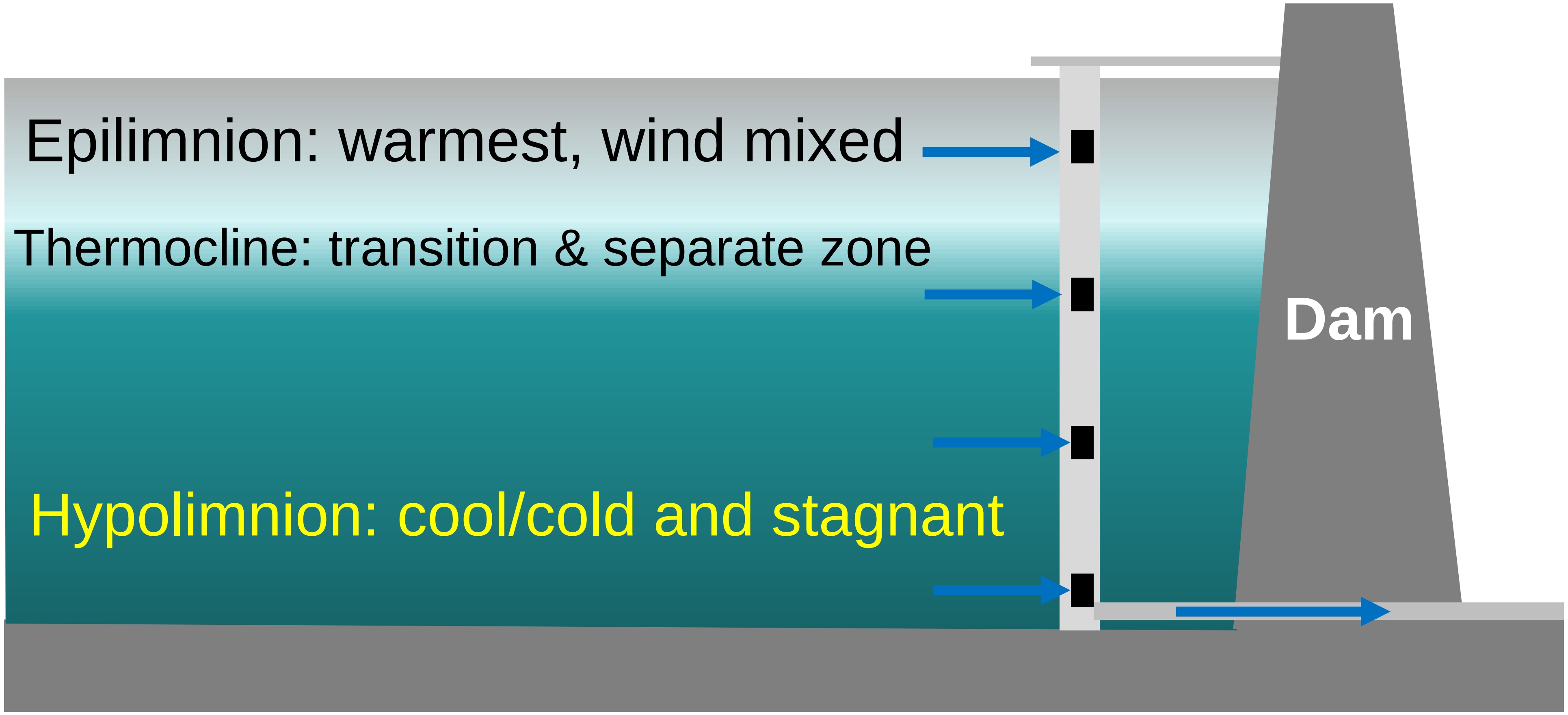
Density stratification



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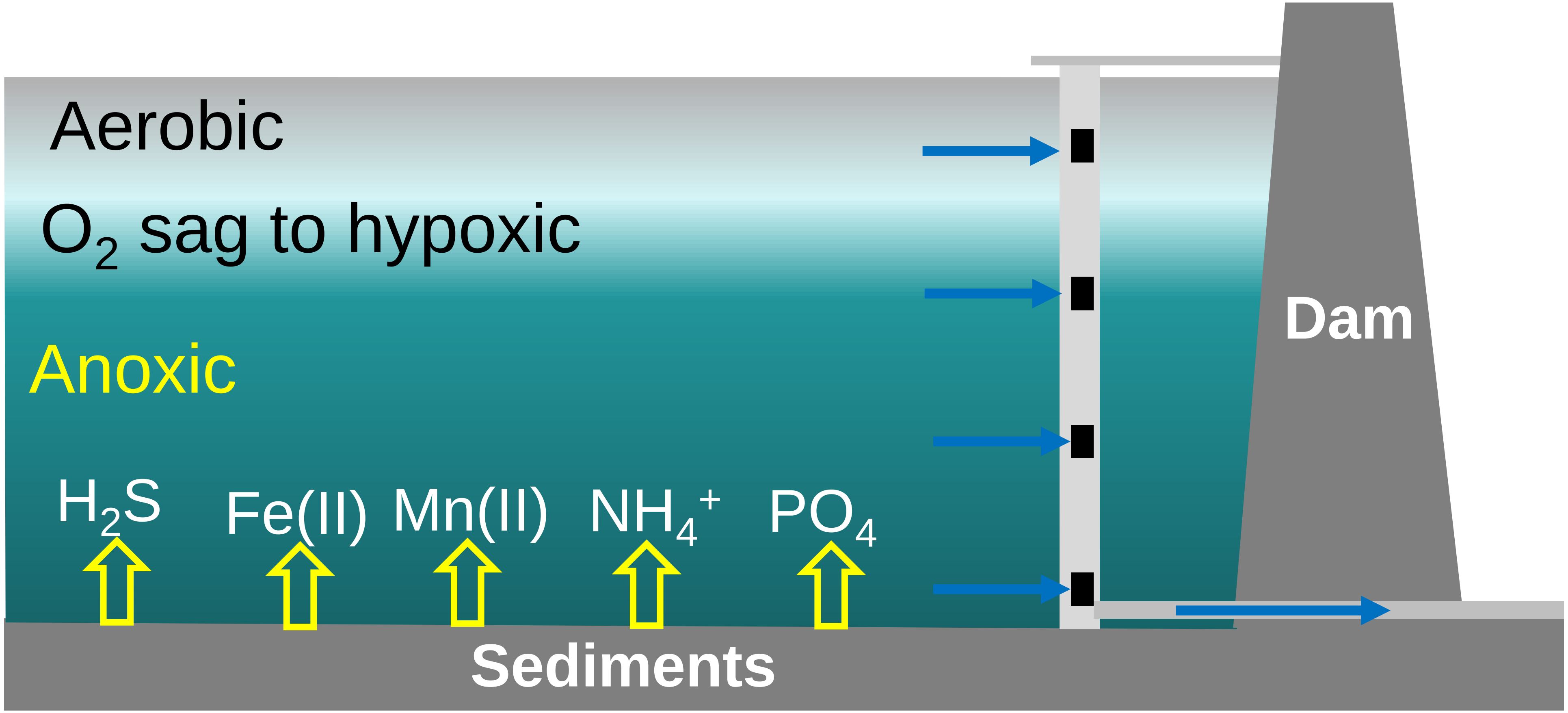
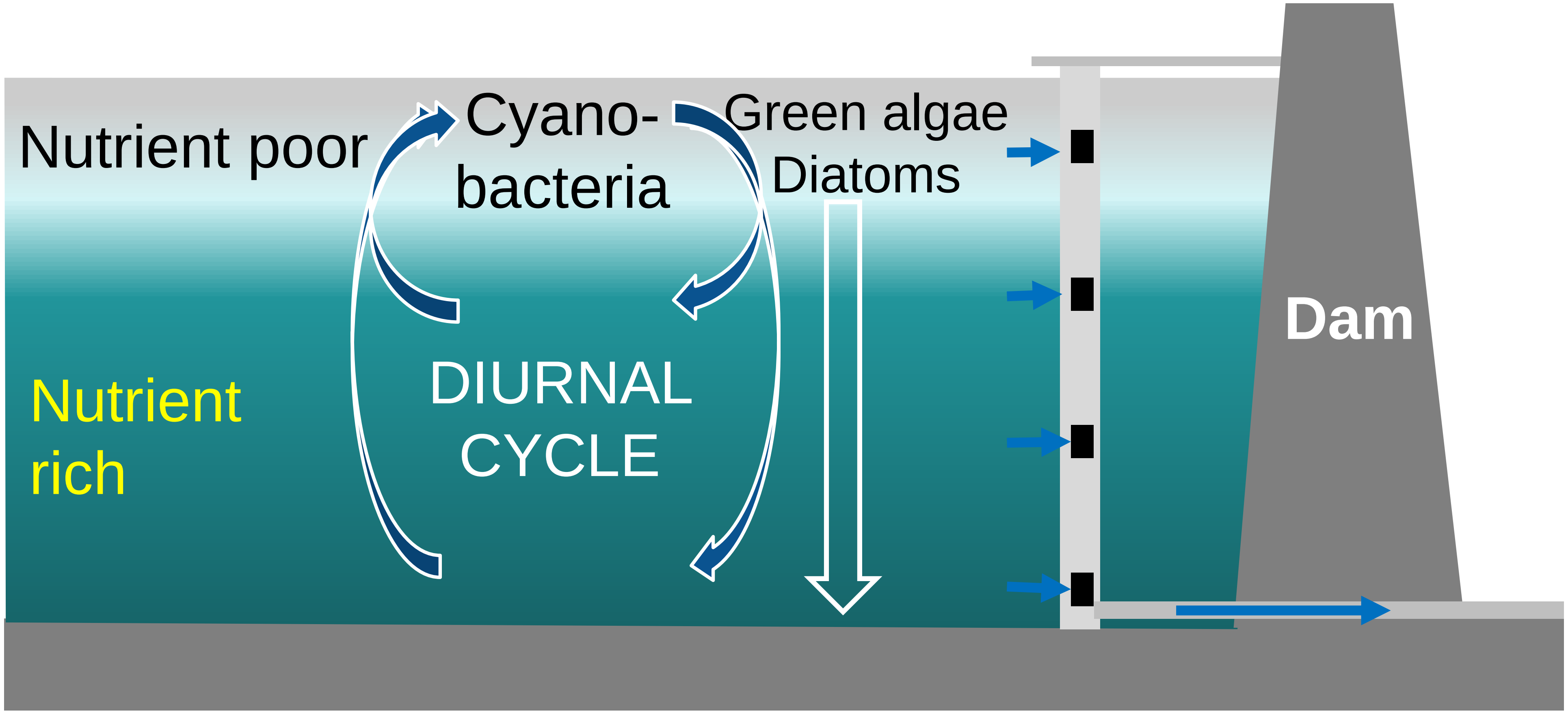
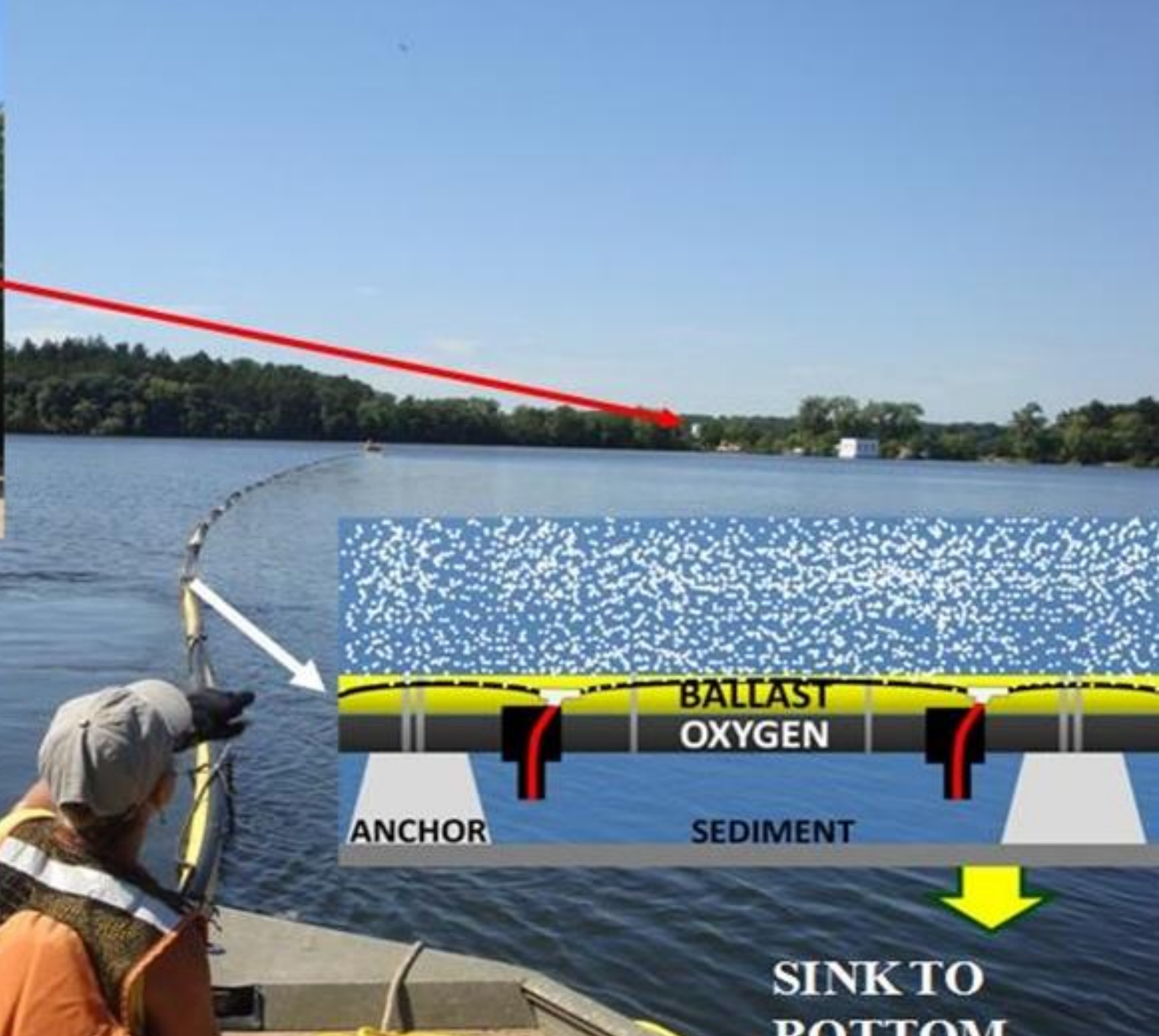
Stratification, anoxia, & nutrients



Cyanobacteria, stratification, & nutrients

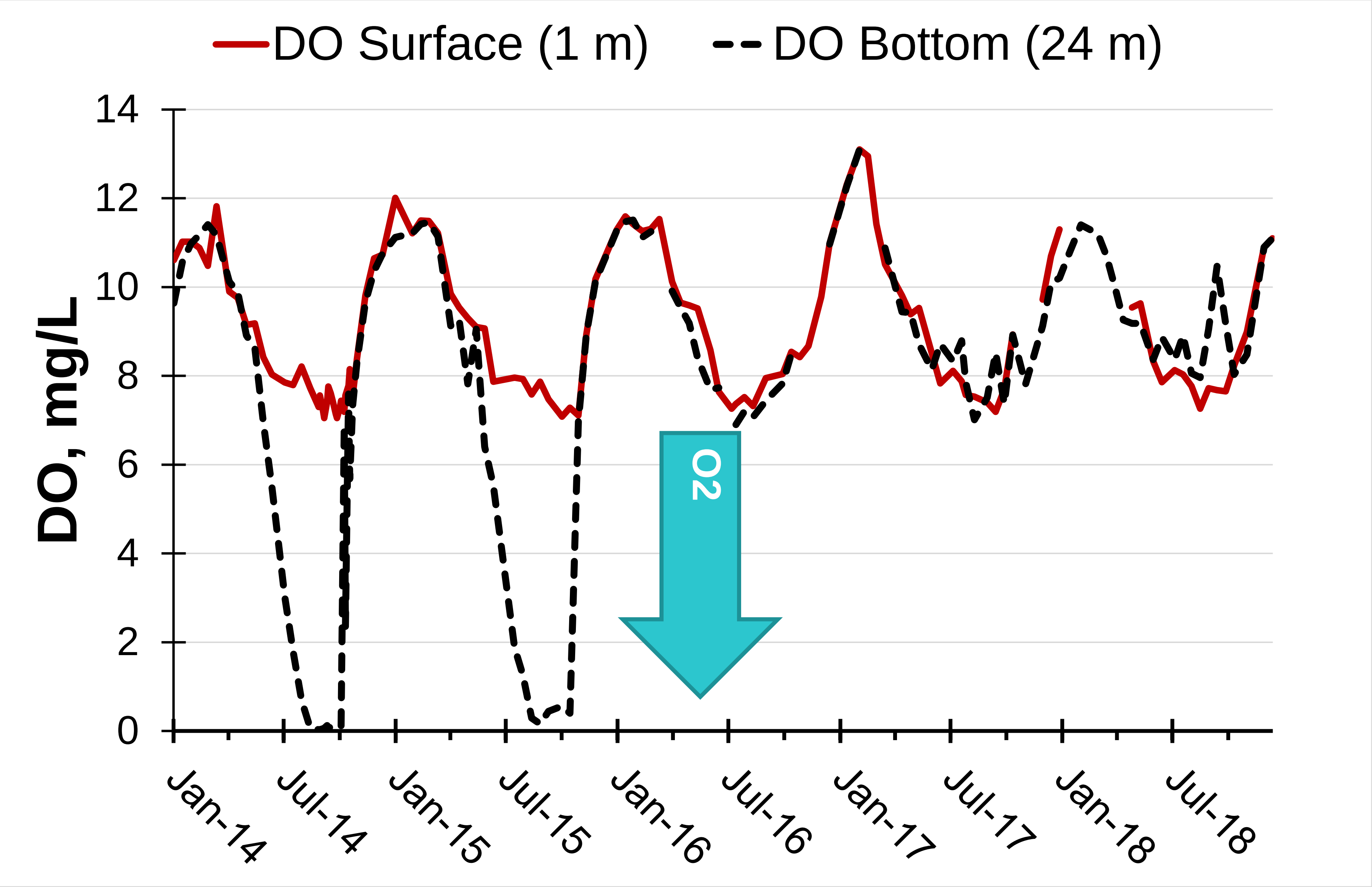




Hypolimnetic Oxygenation

- Destroy anoxia
- Sequester nutrients
- Limit cyanobacteria growth

Aurora Reservoir, CO



Benefits

- 90% reduction in T&O complaints
- 3 YR return on $1M cost from chemical and GAC savings

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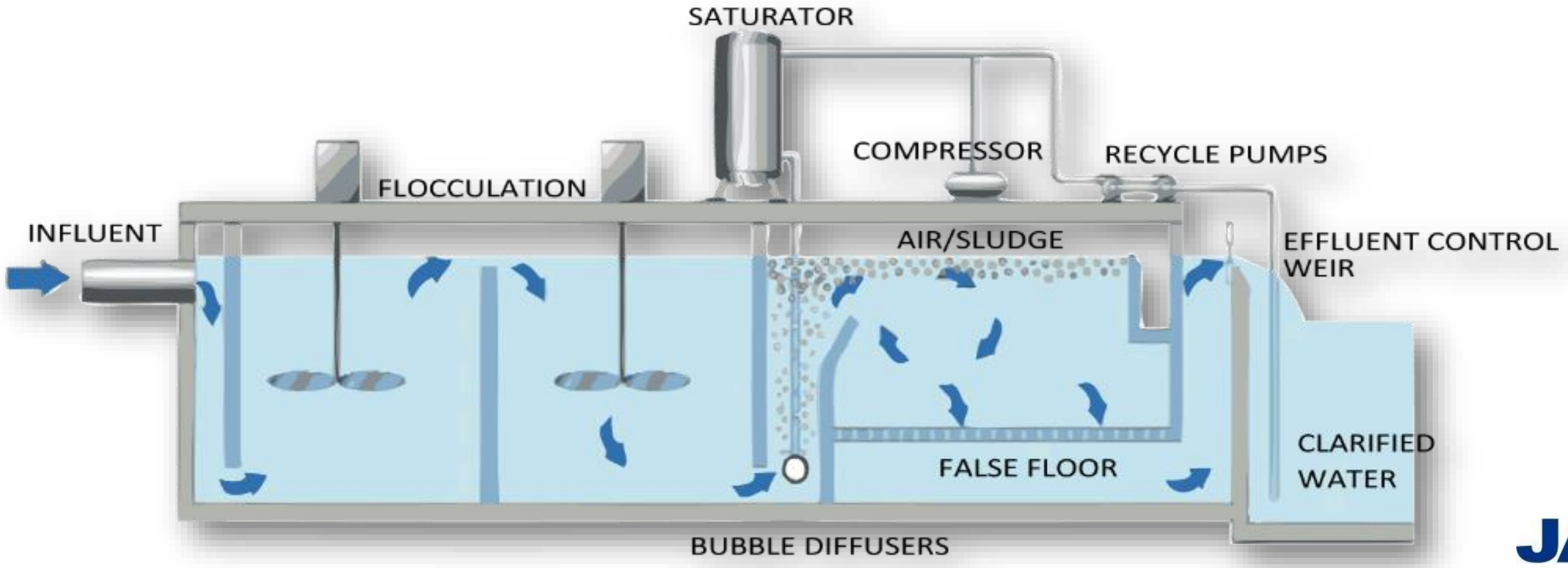
Dissolved Air Flotation

Challenges with conventional coagulation and clarification

- Minimizing turbidity not sufficient to remove algae and cyanobacteria.
- Mechanisms vary for cell removal. Cyanobacteria will be the last phytoplankton cells to be removed.
- High alum dose for anatoxin-a
- Little microcystin removal.
- Toxin release in some cases.



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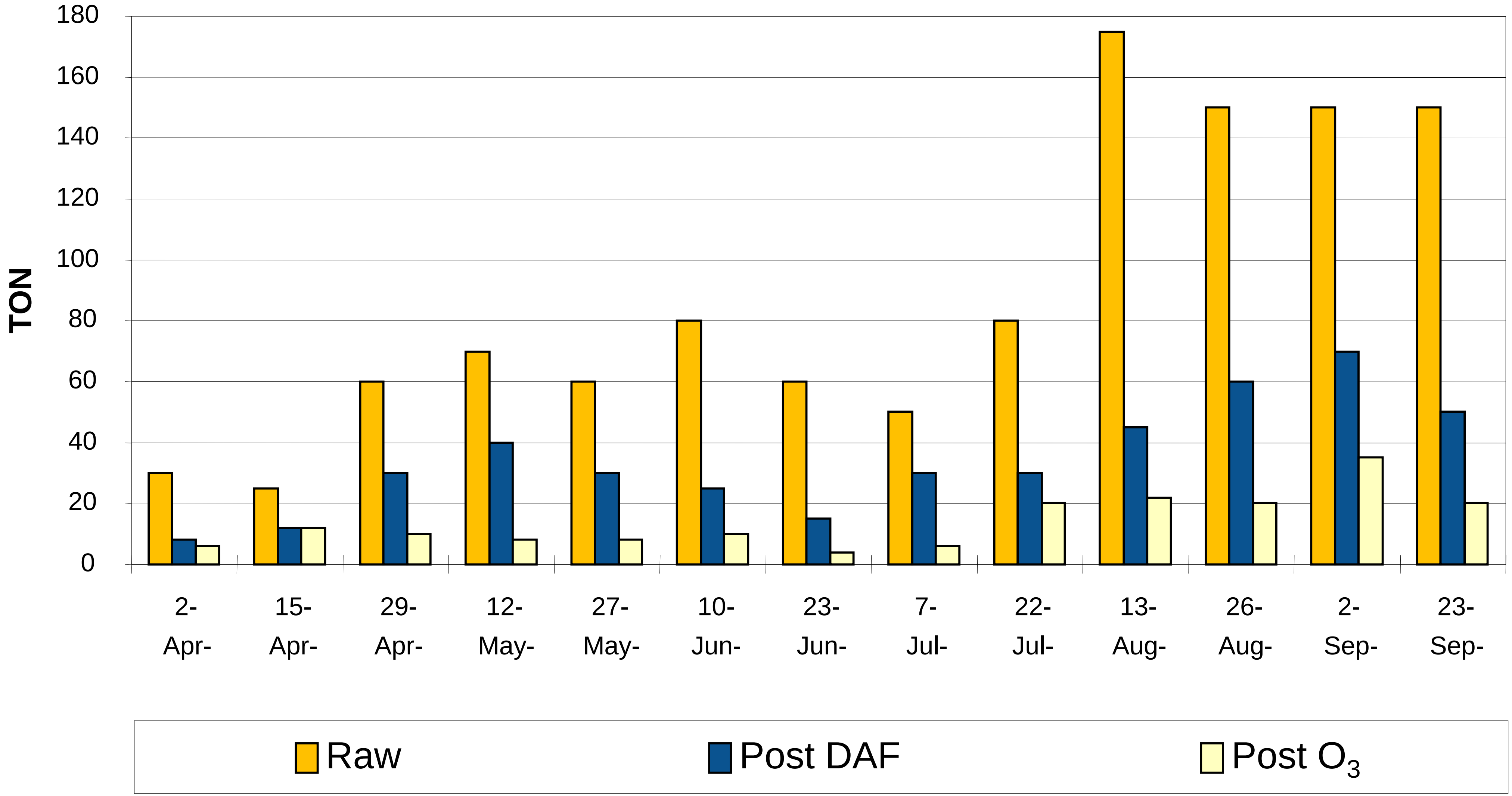
Winnipeg high-rate DAF

- One of the first high-rate DAF installations for a large (105 mgd) WTP
- Extensive piloting of conventional and high-rate DAF reduced construction costs

Winnipeg pilot results - DAF & ozone



Bellingham WA, Lake Whatcom

DAF selected for algae removal

- Lake source
  - Discontinued lake flushing and reduced intake flow
- Turbidity is typically low, < 0.5 NTU
- In-line filtration plant
  - Reduced filter runs to 3.5 hours during algae bloom

Bellingham DAF commissioning September 2017

Bellingham filter performance before and after DAF

	Fall 2017 (before DAF)	Fall 2018 (with DAF)
Average filter run time (hours)	12	53
Average unit filter run volume (UFRV) (gal/hr)	2,400	10,800
Filter influent turbidity (NTU)	0.48	0.1 to 0.2 (70% reduction)
Filter influent particle counts (#/mL)	3,640	100
Backwash water saved (gal/day)		300,000

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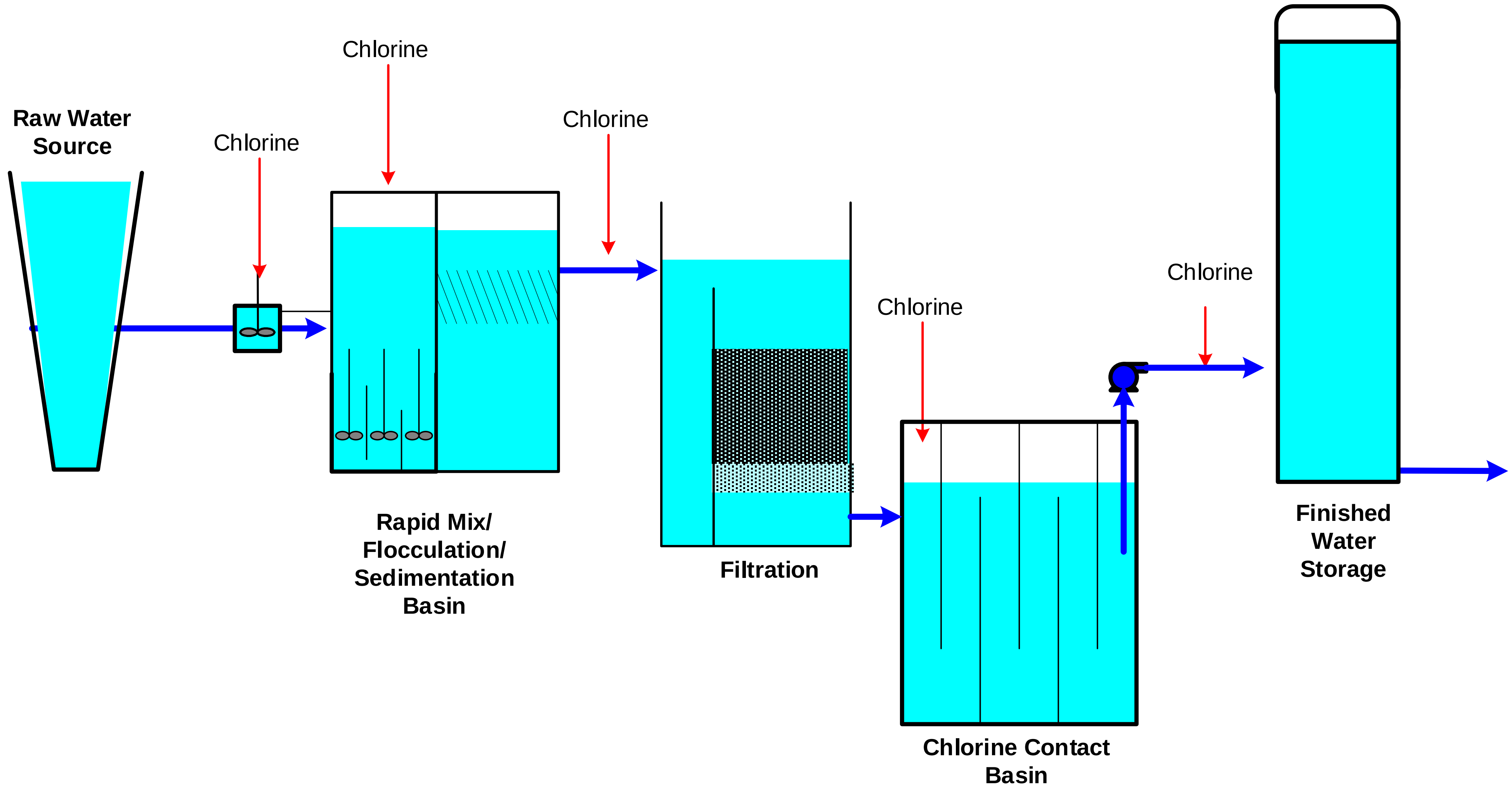
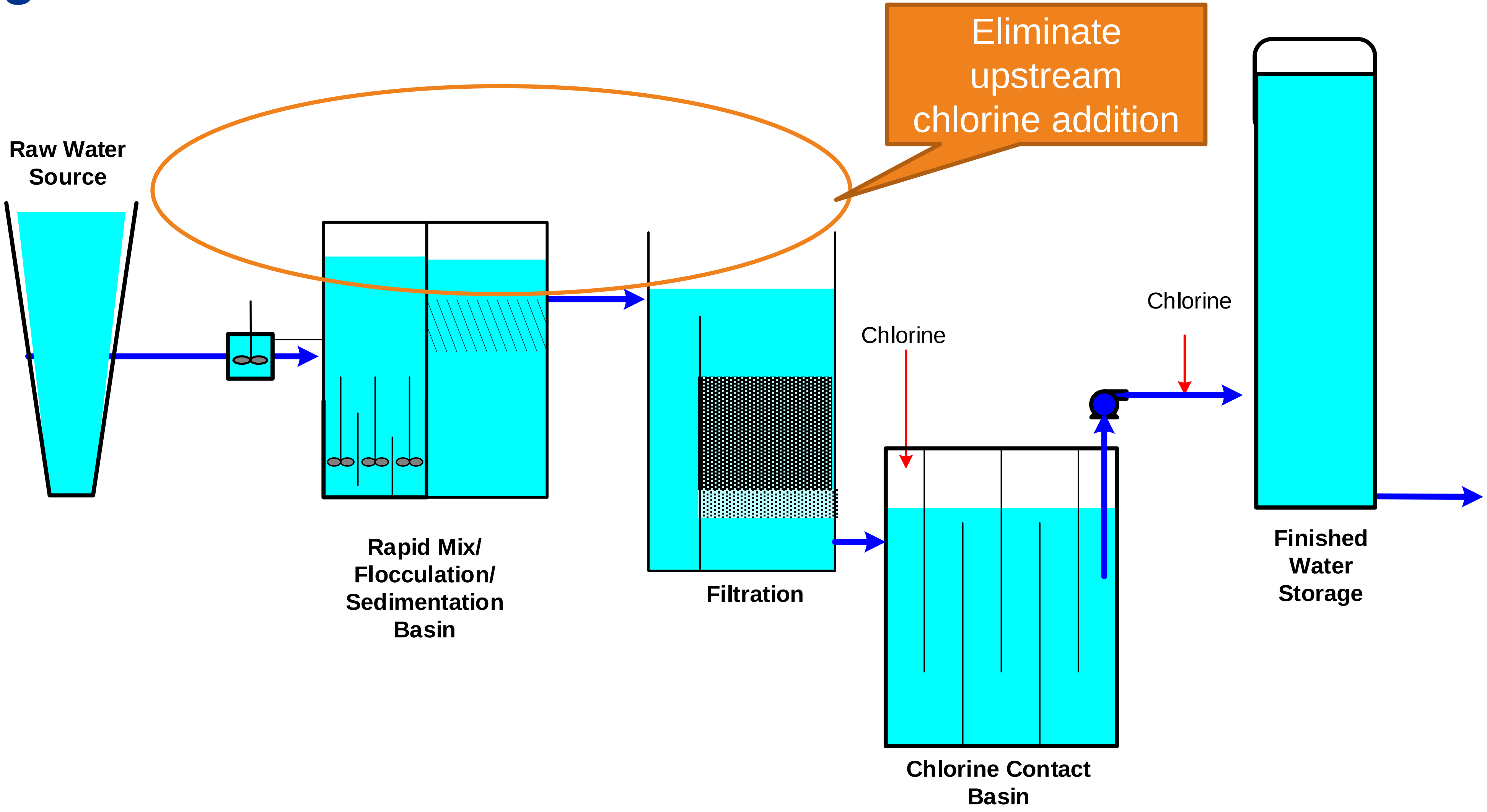
Biological Filtration

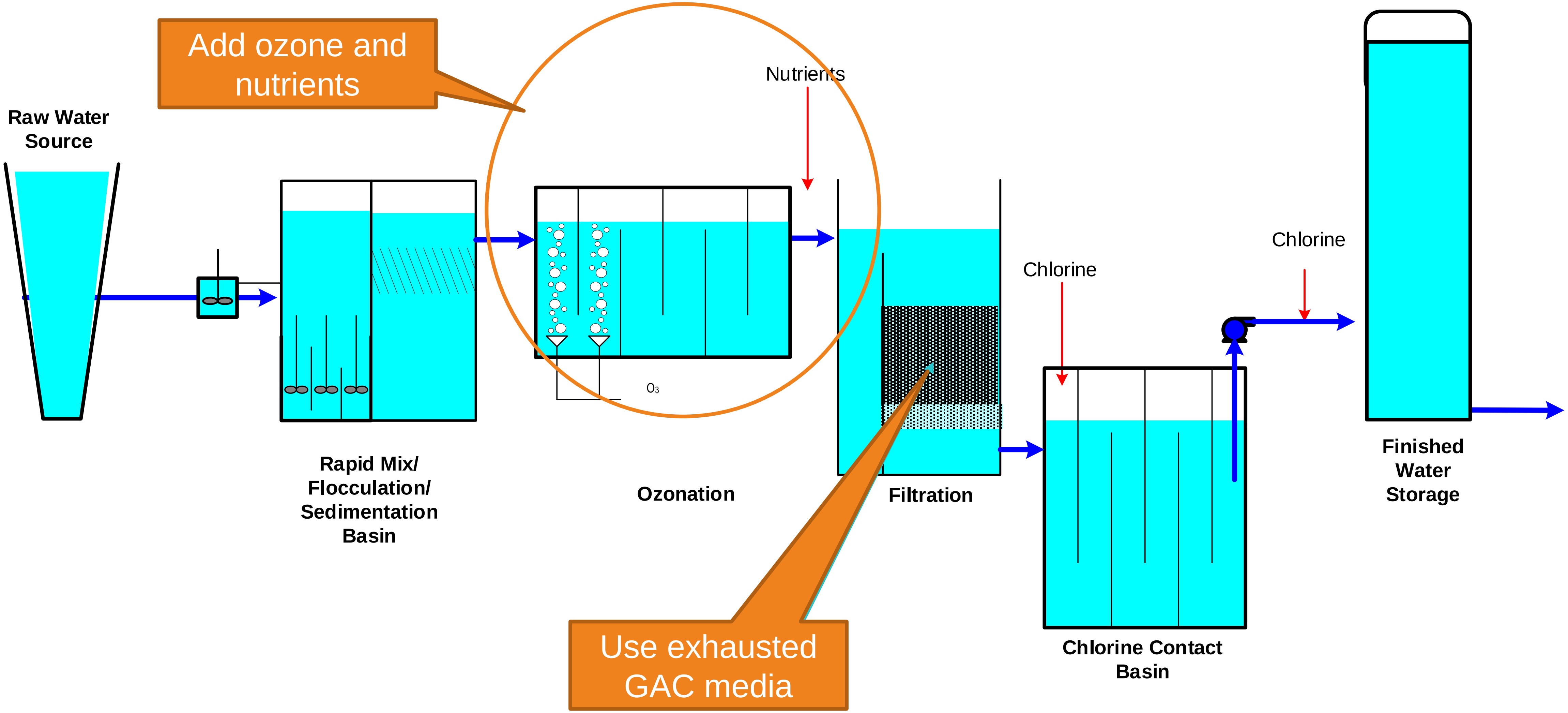
Conventional filtration



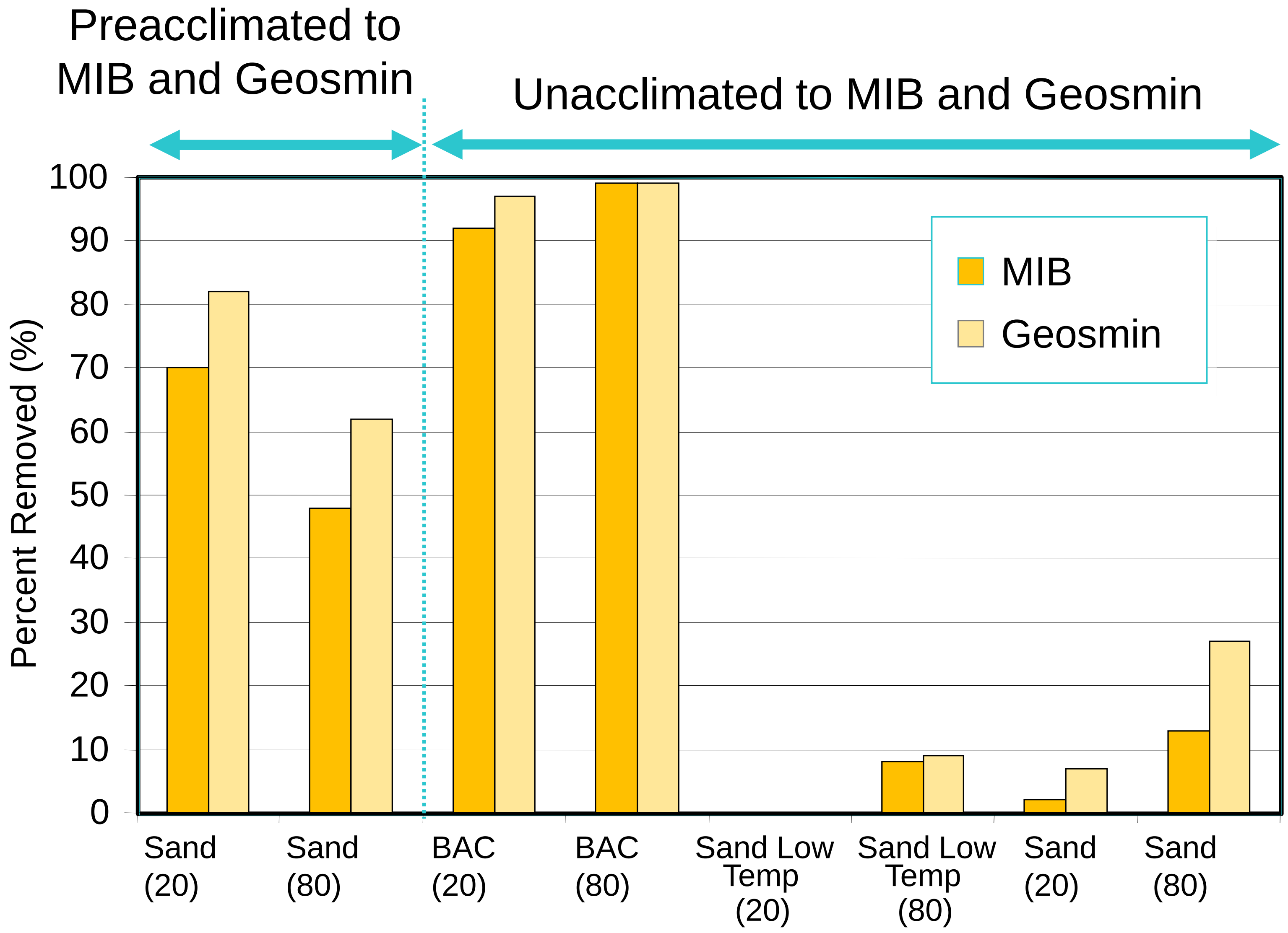
Biological filtration – the minimum



Biological filtration - enhanced



In pilot studies, both sand and GAC media biological filters demonstrate reduction in T&O compounds



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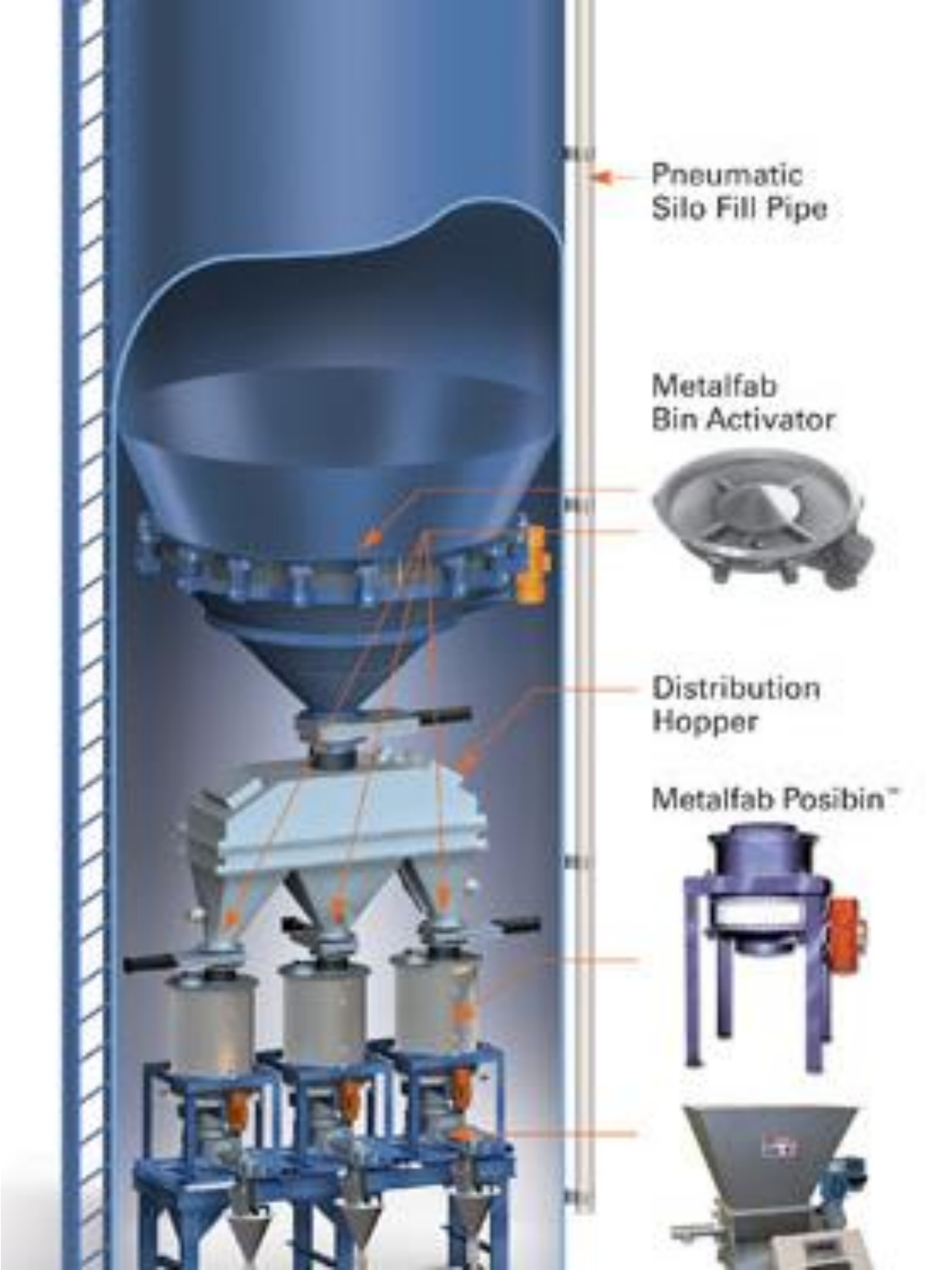
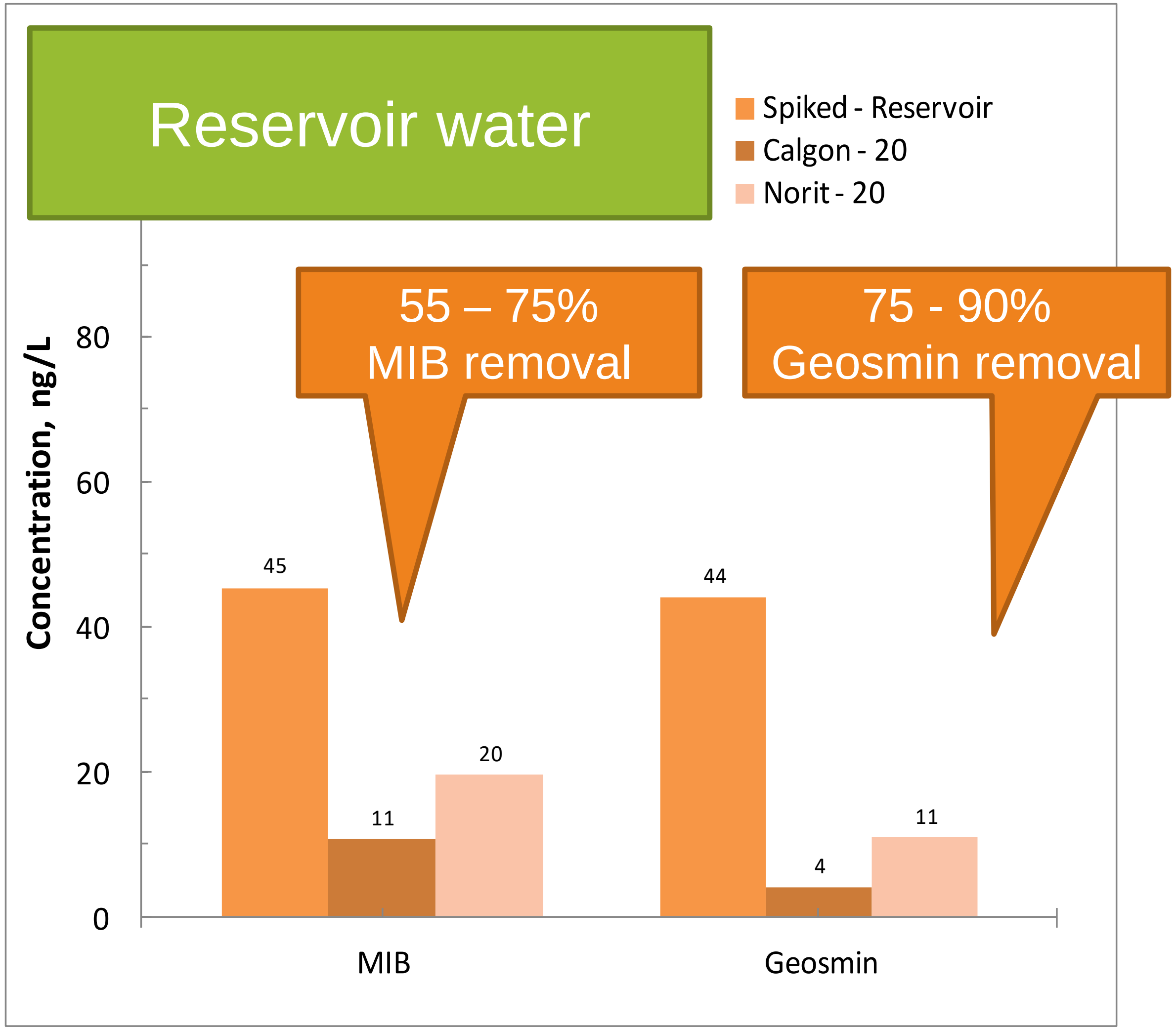
Activated Carbon

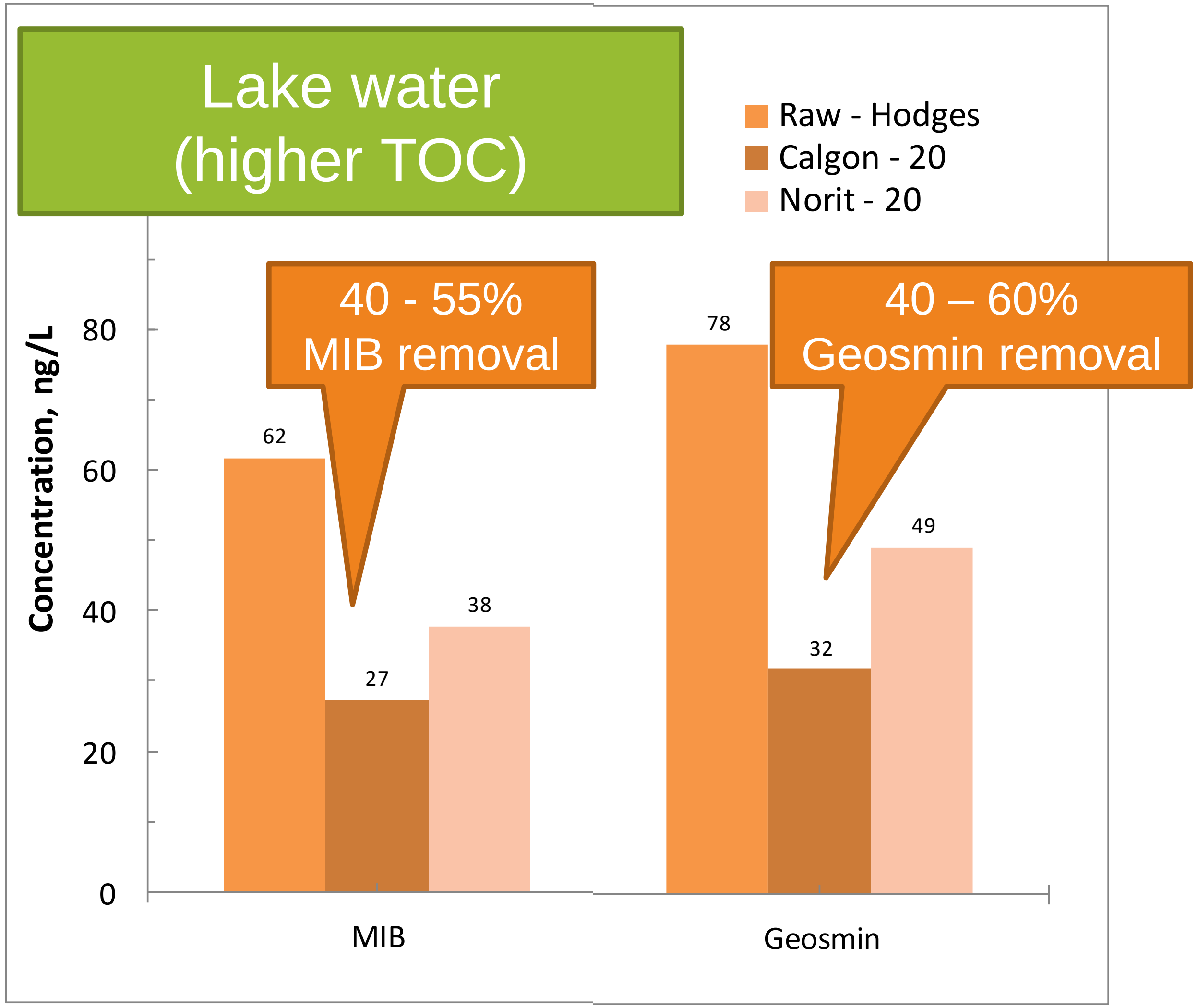
Powdered Activated Carbon

- Most common approach for T&O
- Usually temporary or seasonal use
- Added with other coagulants prior to flocculation and sedimentation
- Can be very effective
- Expensive annual O&M compared to other options



Compared two PACs for T&O control





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Granular activated carbon

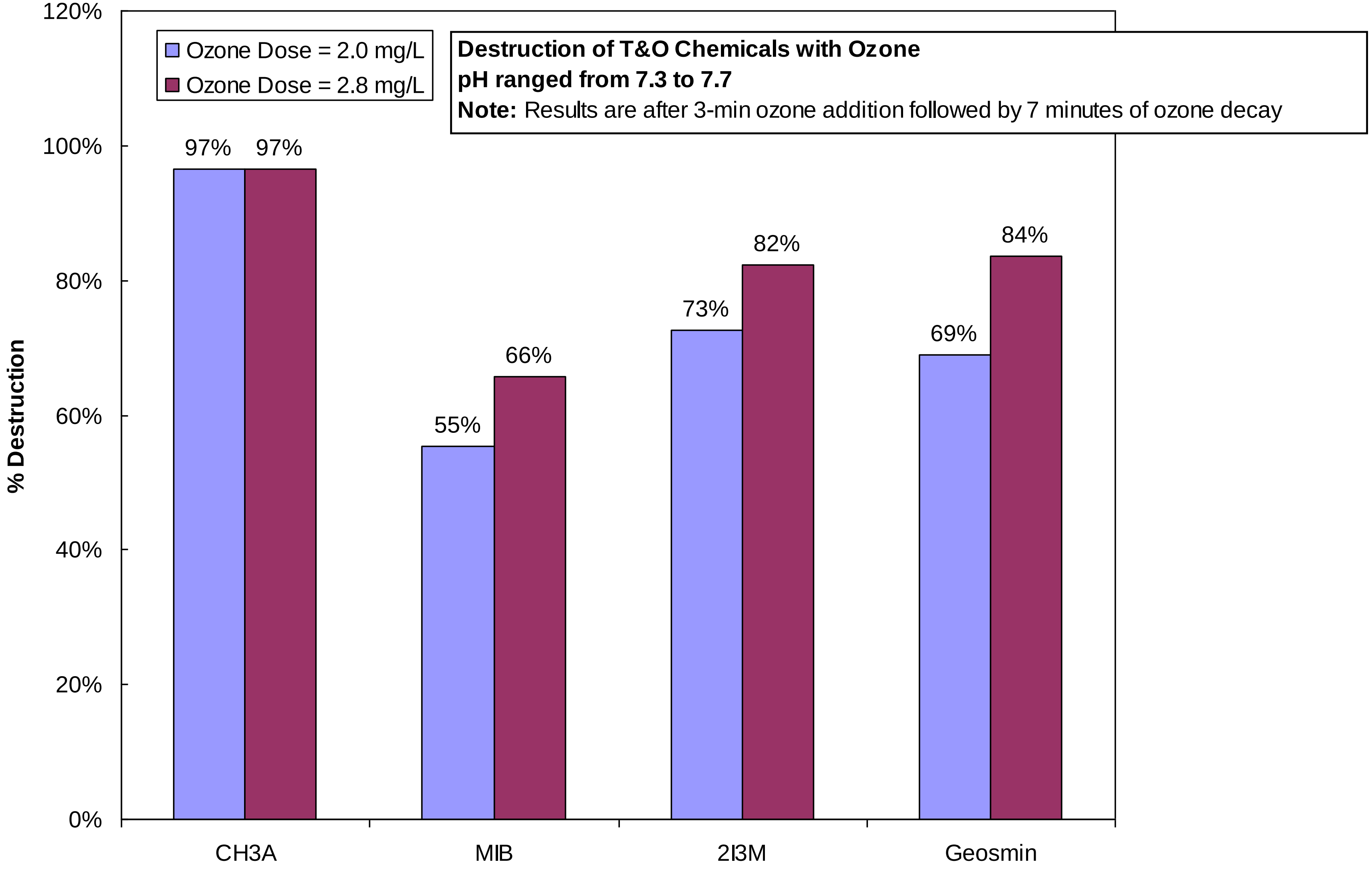
- Can be used as a filter media (in lieu of anthracite)
- Can be installed as GAC contactors downstream of filtration

Ozone

Advantages of Ozonation

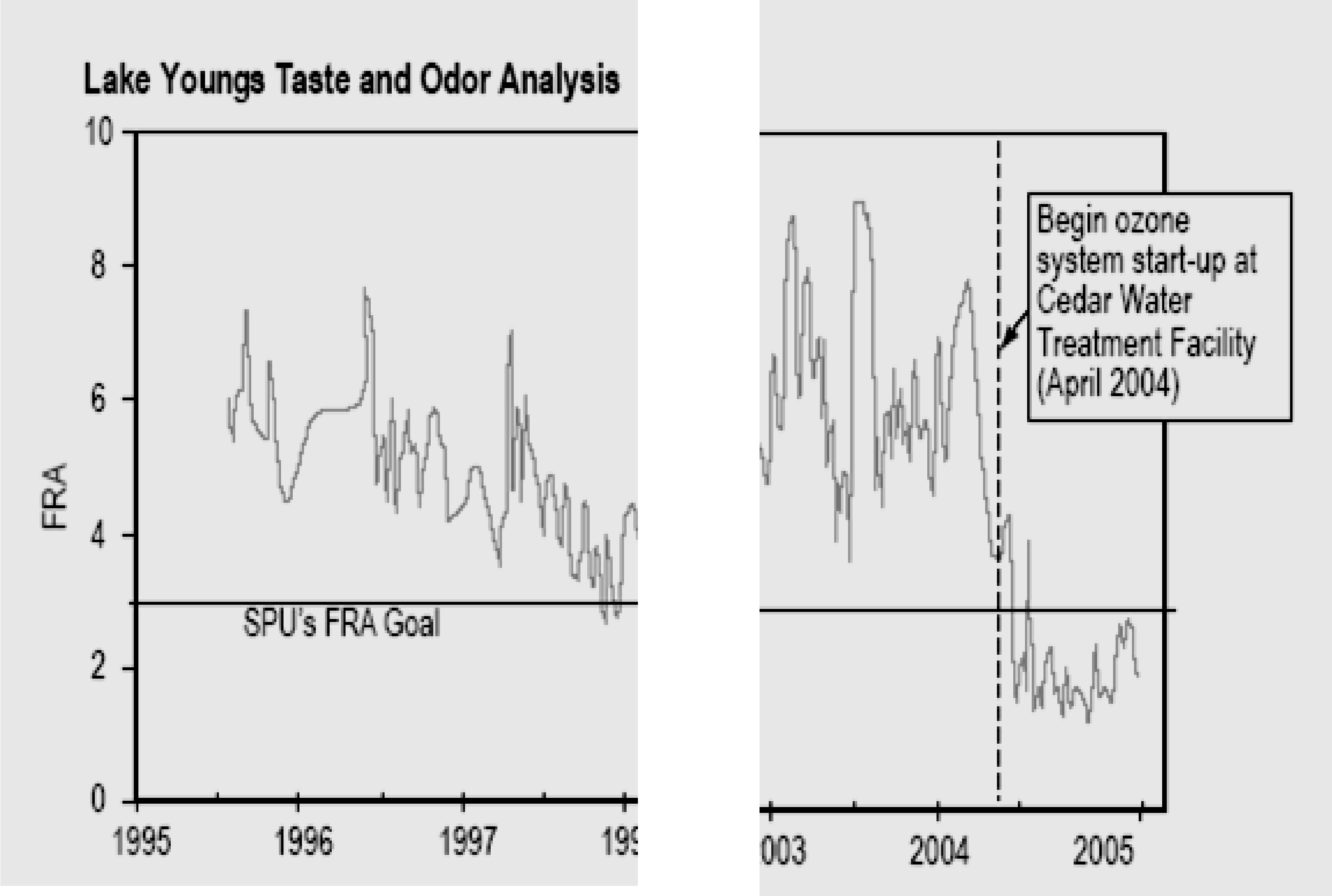
- Taste and odor control
- Disinfection
- Coagulation/ filtration enhancement
- Oxidation
- Biological filter enhancement/
  TOC removal

Destruction of T&O in raw water



Ozone effectiveness measured with Flavor Rating Assessment

Cedar Water Treatment Facility, SPU



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Other Oxidants

Fishy/Swampy/Grassy T&O Control

	>50% Removal in CRW/SPW					
	ClO_2	Cl_2			$KMnO_4$	PAC
Fishy/Swampy/Grassy T&O	**1-hr**	**5-min**	**25-min**	**1-hr**	**1 mg/L**	**25 mg/L**
Dimethyl Trisulfide	Yes	Yes	Yes	Yes	Yes	Yes
2,3-Benzopyrrole (Indole)	Yes	Yes	Yes	Yes	Yes	Yes
Dimethyl Disulfide	Yes	Yes	Yes	Yes	Yes	No
Cis, 3-Hexen-1-ol	No	No	Yes**	Yes	NA	No
Cis, 4-Heptenal	No	No	Yes**	Yes	Yes	No
Trans, 2-cis, 6-Nonadienal	No	No	Yes**	Yes	NA	Yes
Cis, 3-Hexenyl Acetate	No	No	No	Yes*	Yes	Yes
1-Heptanal	No	No	No	No	No	Yes
Trans, trans-2,4-Heptadienal	No	No	No	No	Yes	Yes
2-Isobutyl-3-methoxypyrazine	No	No	No	No	No	Yes
Trans, trans-2,4-Decadienal	No	No	No	No	NA	Yes
1-Hexanal	No	No	No	No	No	No

*Yes in 50% SPW, no in 100% CRW and 100% SPW

**Yes in 100% SPW, no in 100% CRW

Summary of Results

Treatment Technique	Geosmin Removal	MIB Removal	TON Reduction
DAF			50 – 75%
DAF + Ozone			50 – 85%
Biological Sand Filtration	5 – 70%	10 – 80%	
Biologically Active Carbon (BAC)	>90%	>95%	
Powdered Activated Carbon (PAC)	40 – 90%	40 – 75%	
Ozone	55 – 90%	70 – 90%	
UV-Peroxide AOP	>95%	>90%	

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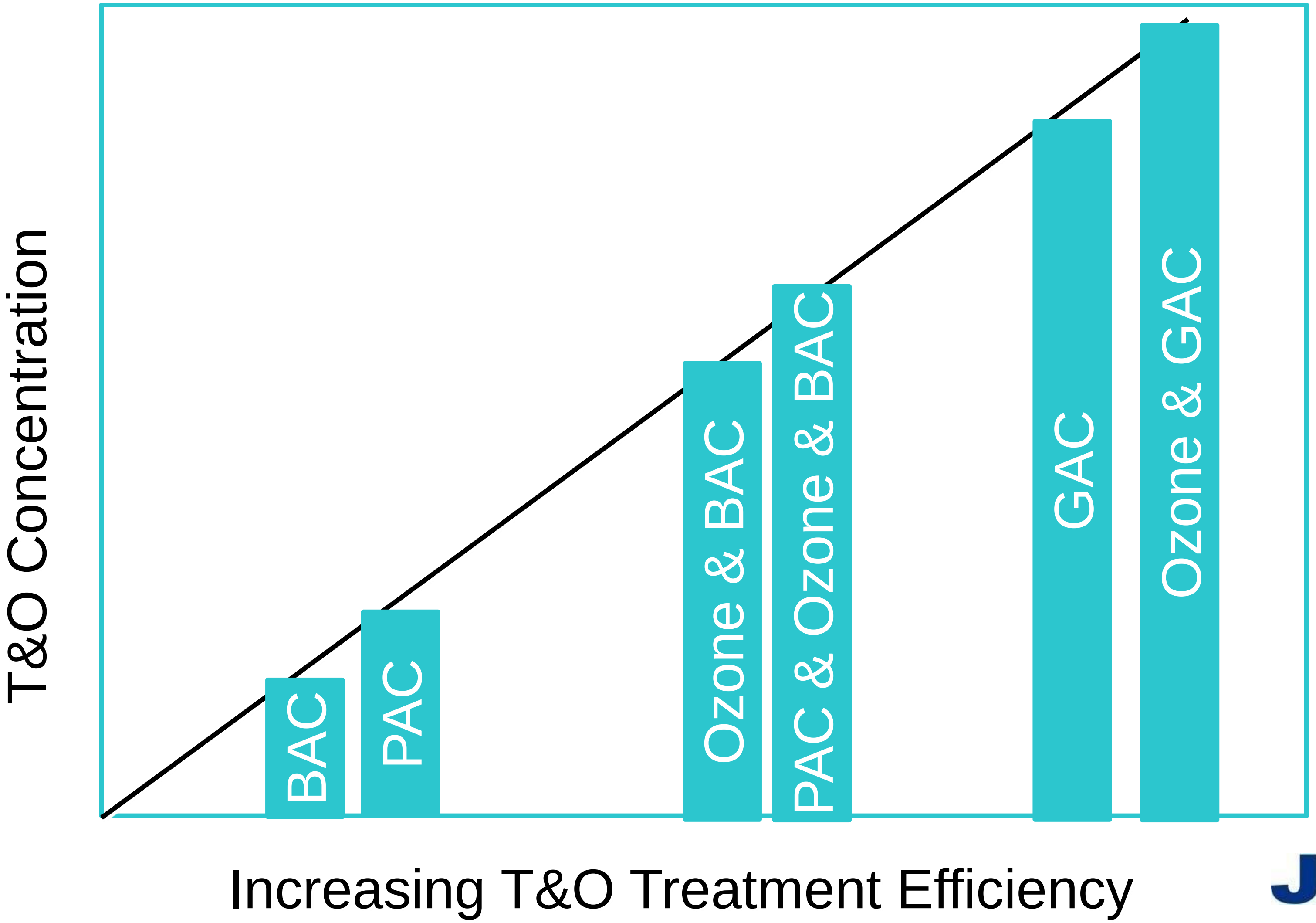
Treatment Technologies Associated with Increasing T&O



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THANK YOU

References and Acknowledgements:

1. “Effect of Powdered Activated Carbon Base Material and Size on Disinfection By-Product Precursor and Trace Organic Pollutant Removal,” Master’s thesis by Susan Ennis Dun, North Carolina State University, 2011.
2. CH2M HILL Applied Sciences Laboratory
3. Kerry Meyer/CH2M HILL, et al, “Biofiltration for MIB and Geosmin Removal”, ACE 2005 podium presentation.
4. Others as cited.

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