WCWC Walkerton Clean Water Centre
An agency of the Government of Ontario

CWAE Centre de Walkerton pour l'assainissement de l'eau
Un organisme du gouvernement de l'Ontario

Blue-Green Algae Treatment Challenges: A Large, Small and Household Drinking Water Perspective

2014 Clean & Safe Drinking Water Workshop

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March 25, 2014

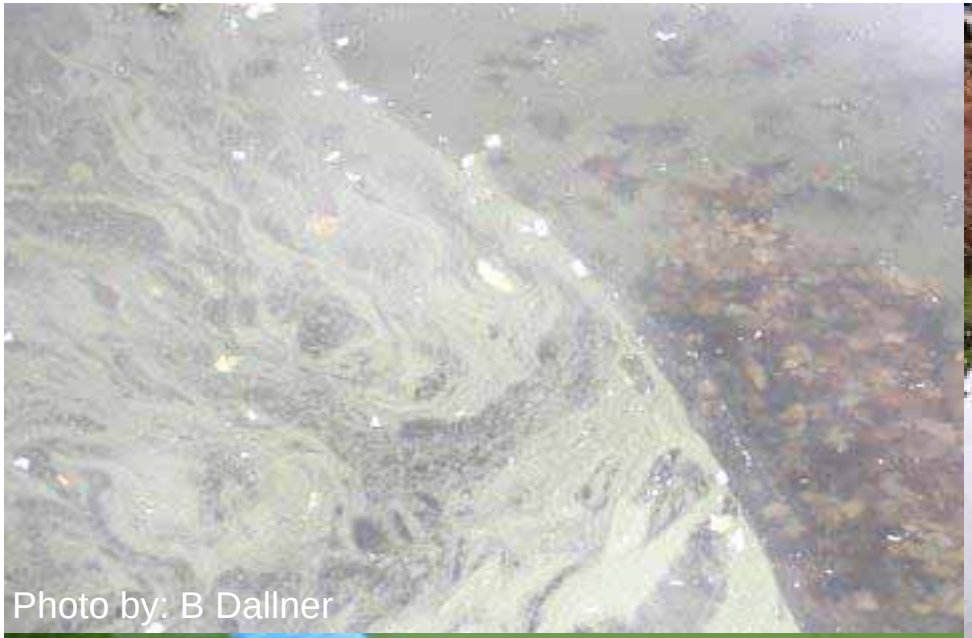


Photo by: B Dallner

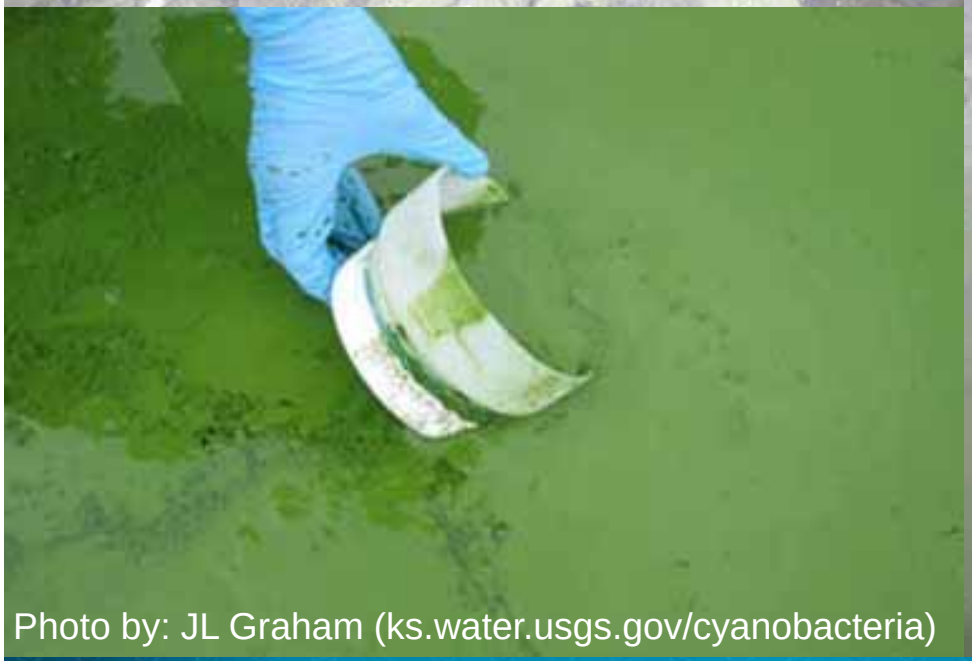


Photo by: JL Graham (ks.water.usgs.gov/cyanobacteria)

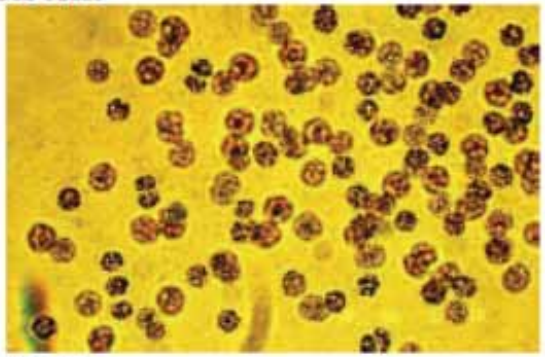
Photo by: B Dallner

Blue-Green Algae = Cyanobacteria

COLONY

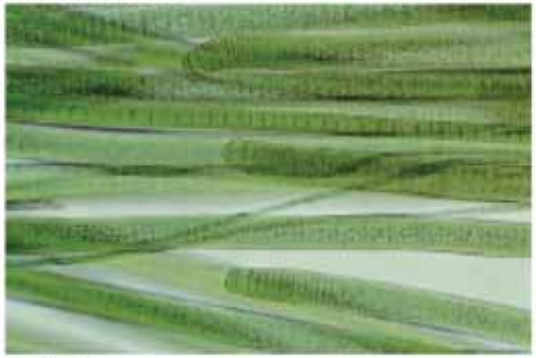
Microcystis

SINGLE CELLS



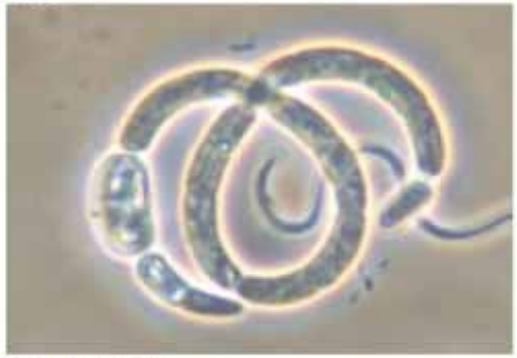
Microcystis

STRAIGHT FILAMENTS



Phormidium

SPIRALING



Cylindrospermopsin

Coiled *Anaboena* showing heterocytes and akinetes

Coiled *Anaboena* showing heterocytes and akinetes

Different shapes and sizes

Photo by: Newcombe, G. (2012)

Introduction

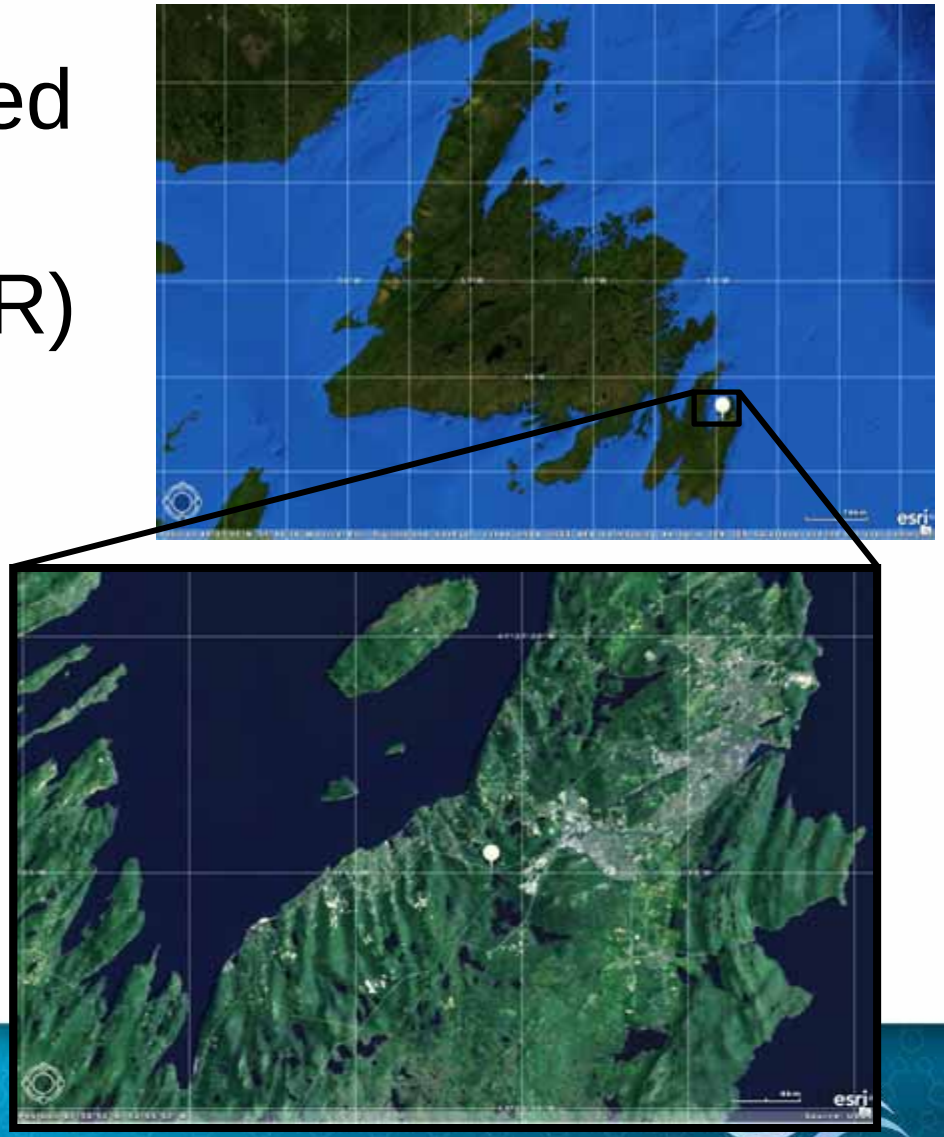
Health Implications:

Cyanotoxins	Health effects
Anatoxin (AnTX)	Nervous system
Saxitoxin (STX)	Nervous system
Microcystins (MC)	Liver Tumor promoting effects
Nodularins (Nod)	Liver
Cylindrospermopsin (CYN)	Liver and kidney Tumor promoting effects

WHO provisional guideline 1.0 µg/L MC-LR
Canadian maximum acceptable concentration 1.5 µg/L MC-LR

Cyanobacteria & Newfoundland

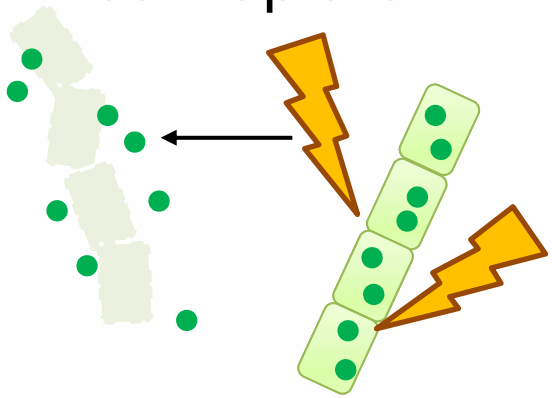
- **2007**: First documented cyanobacteria bloom (0.24-0.36 µg/L MC-LR)
- **2012**: cyanobacterial blooms (MC-LR non-detected)
- **2013**: cyanobacterial blooms (MC-LR non-detected)



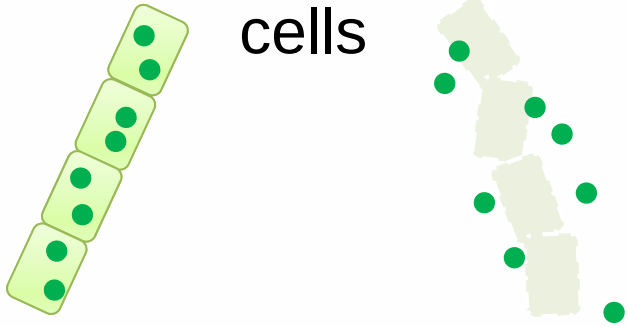
www.env.gov.nl.ca/env/waterres/quality/background/bgalgae.html

Challenges:

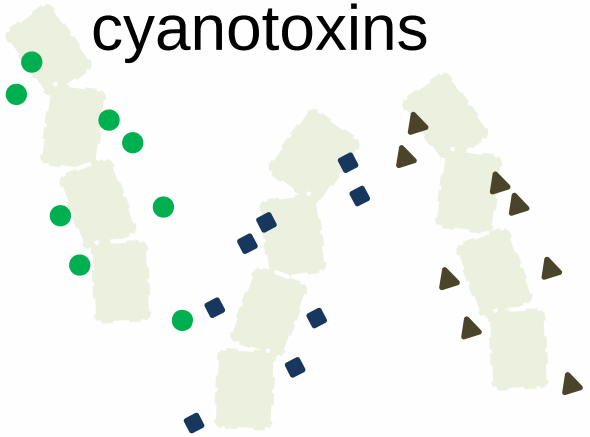
2. Some treatment cause cell rupture



1. Aging cyanobacteria cells



4. Treatment effectiveness varies with specific cyanotoxins



Healthy, young

Unhealthy, aged

Treatment A

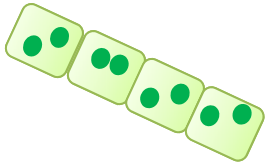
Treatment B

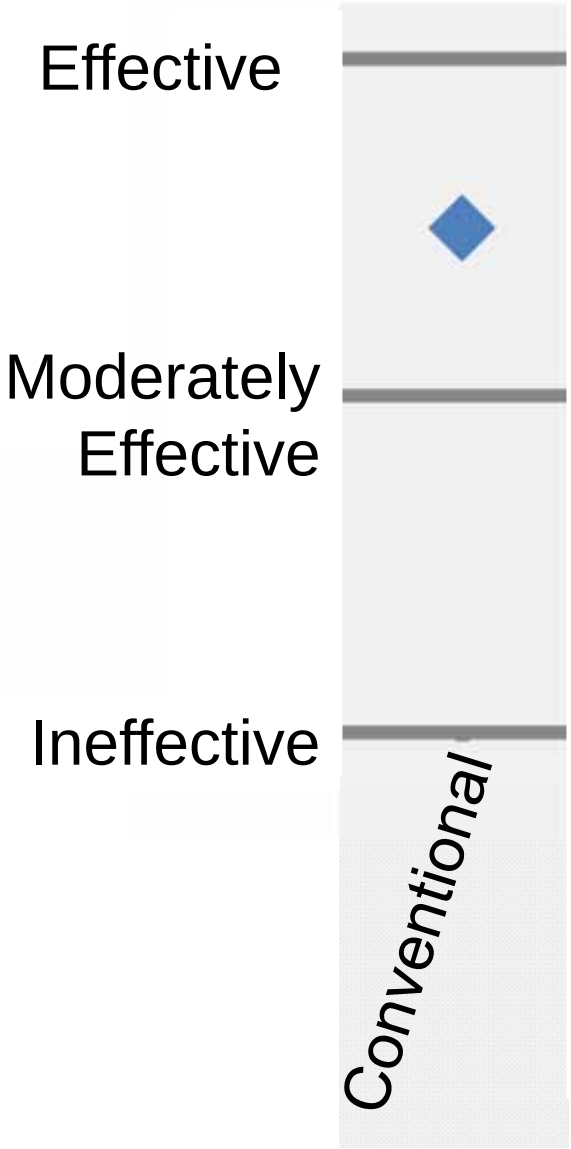
3. Treatment effectiveness varies with intracellular and released cyanotoxins

Water Treatment

- Conventional Treatment Processes
- Dissolved Air Flotation
- Slow Sand Filtration
- Ultrafiltration
- Nanofiltration
- Adsorption (GAC & PAC)
- Oxidation

Intracellular

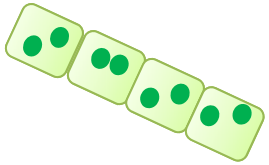


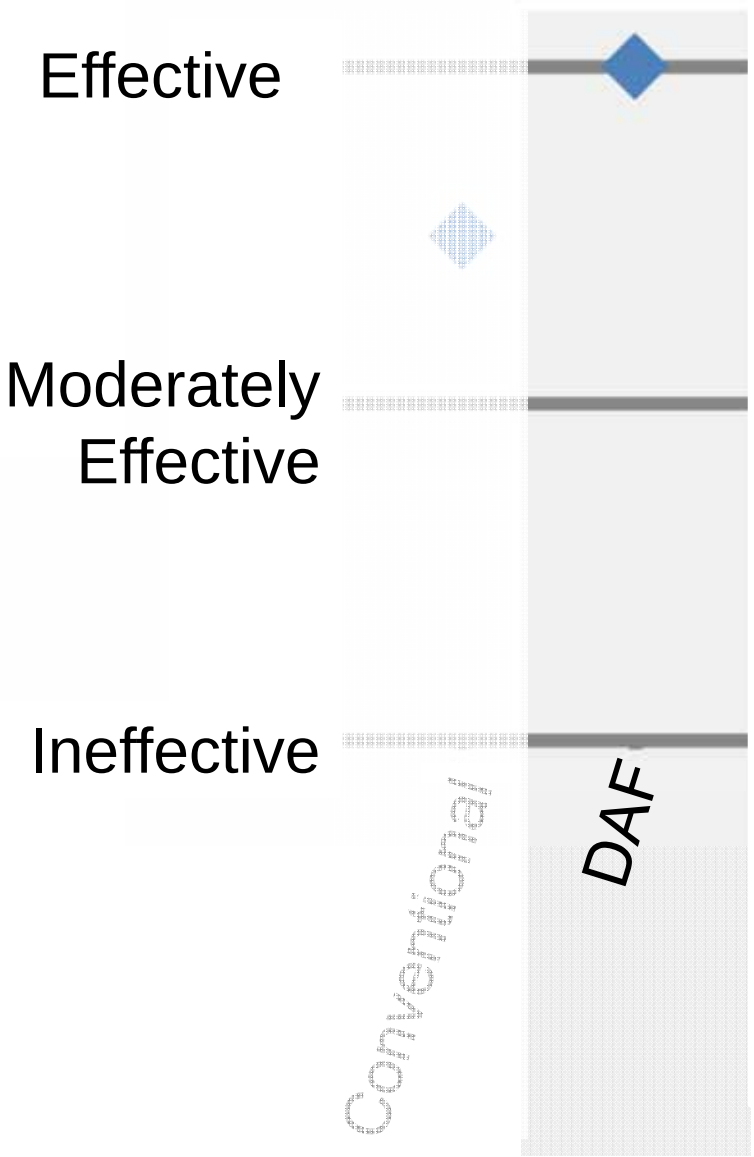


Conventional

- 70-99.9% removal
- Trapped cells could rupture and release toxins
- May be influenced by NOM

Intracellular

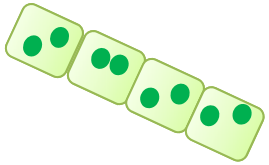


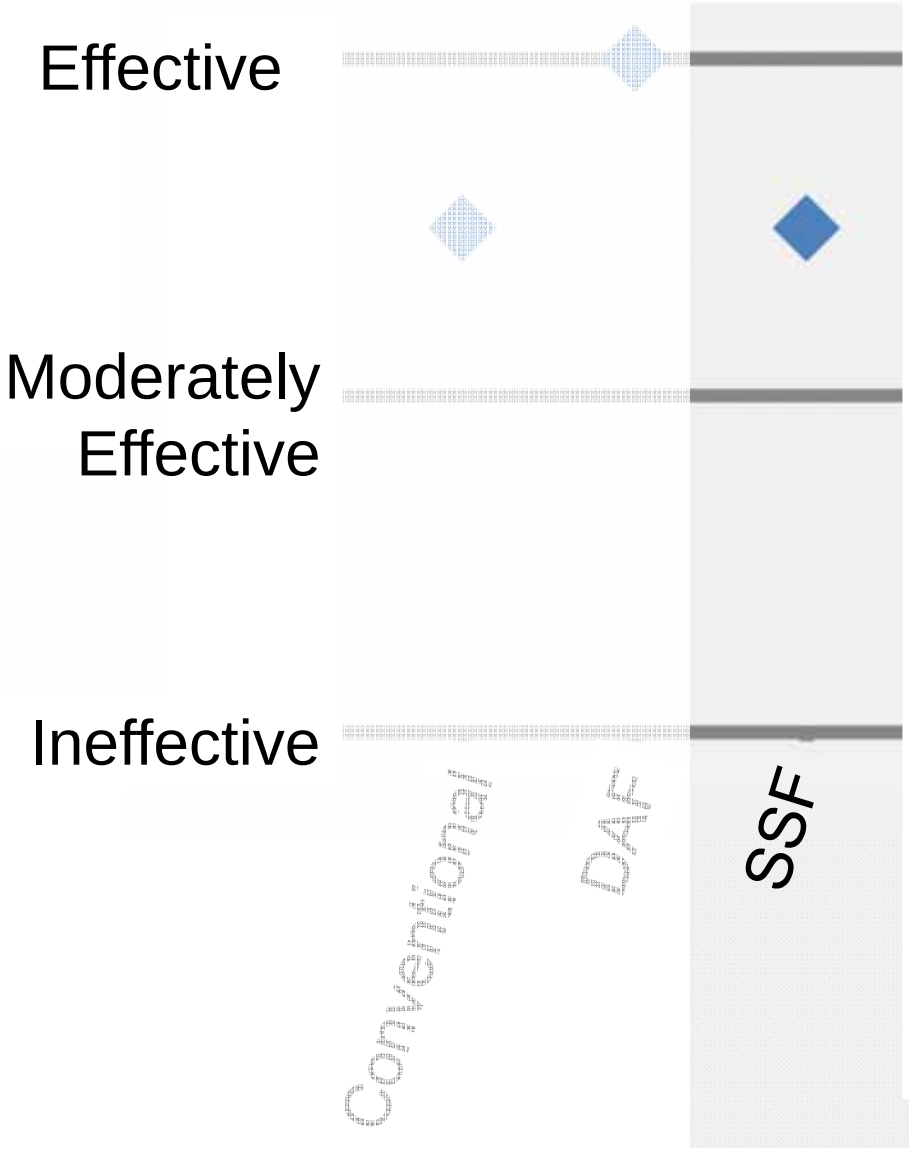


Dissolved Air Flotation

- 93-99% removal
- Sludge must be removed frequently
- Not as influenced by NOM, than conventional

Intracellular

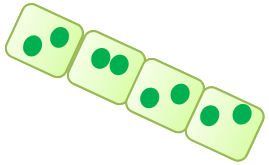


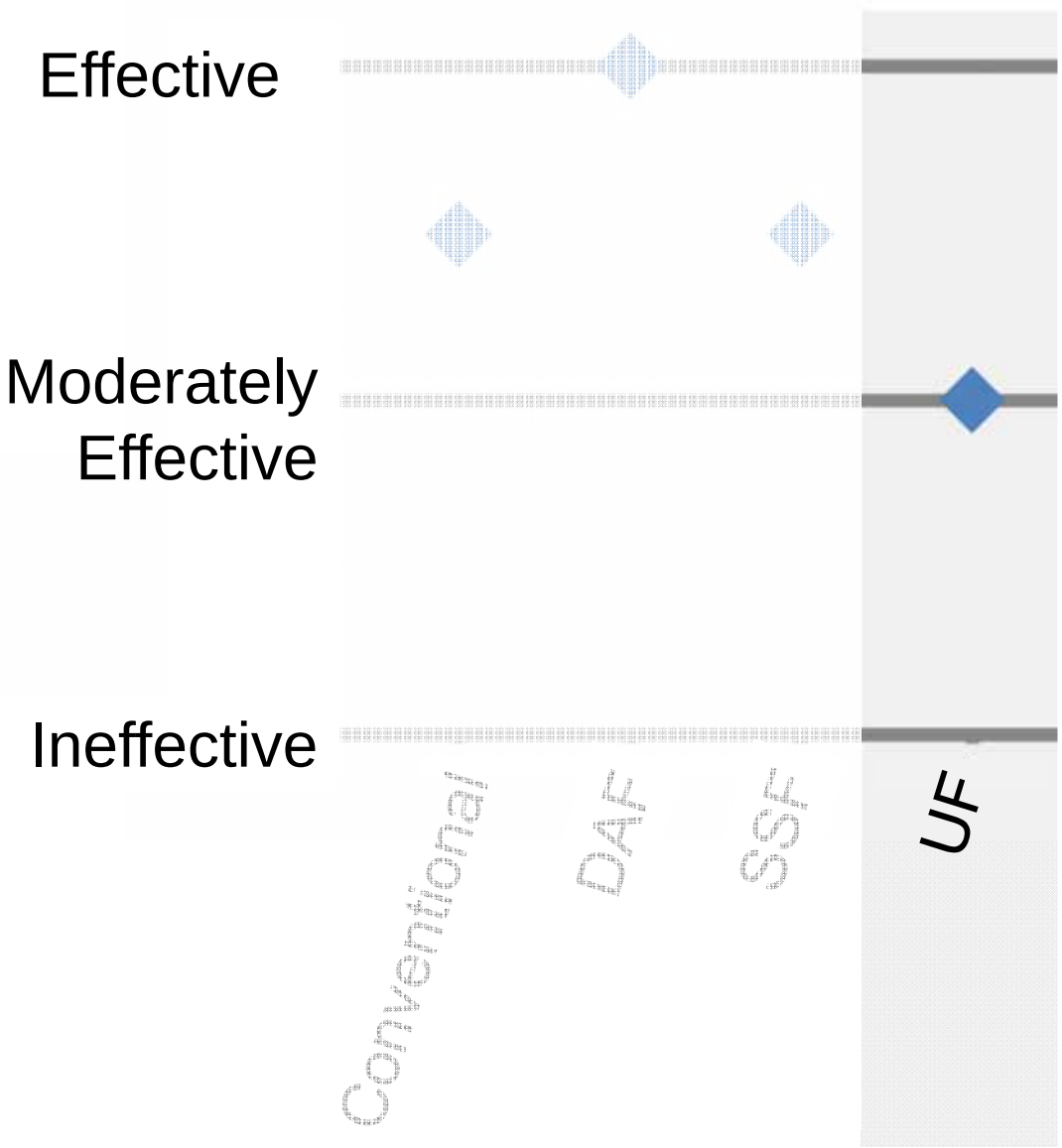


Slow Sand Filtration

- 80-99% removal
- Trapped cells could rupture and release toxins
- Vulnerable between maintenance and at low temperatures

Intracellular

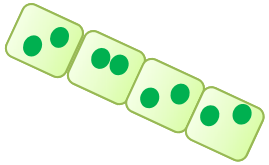


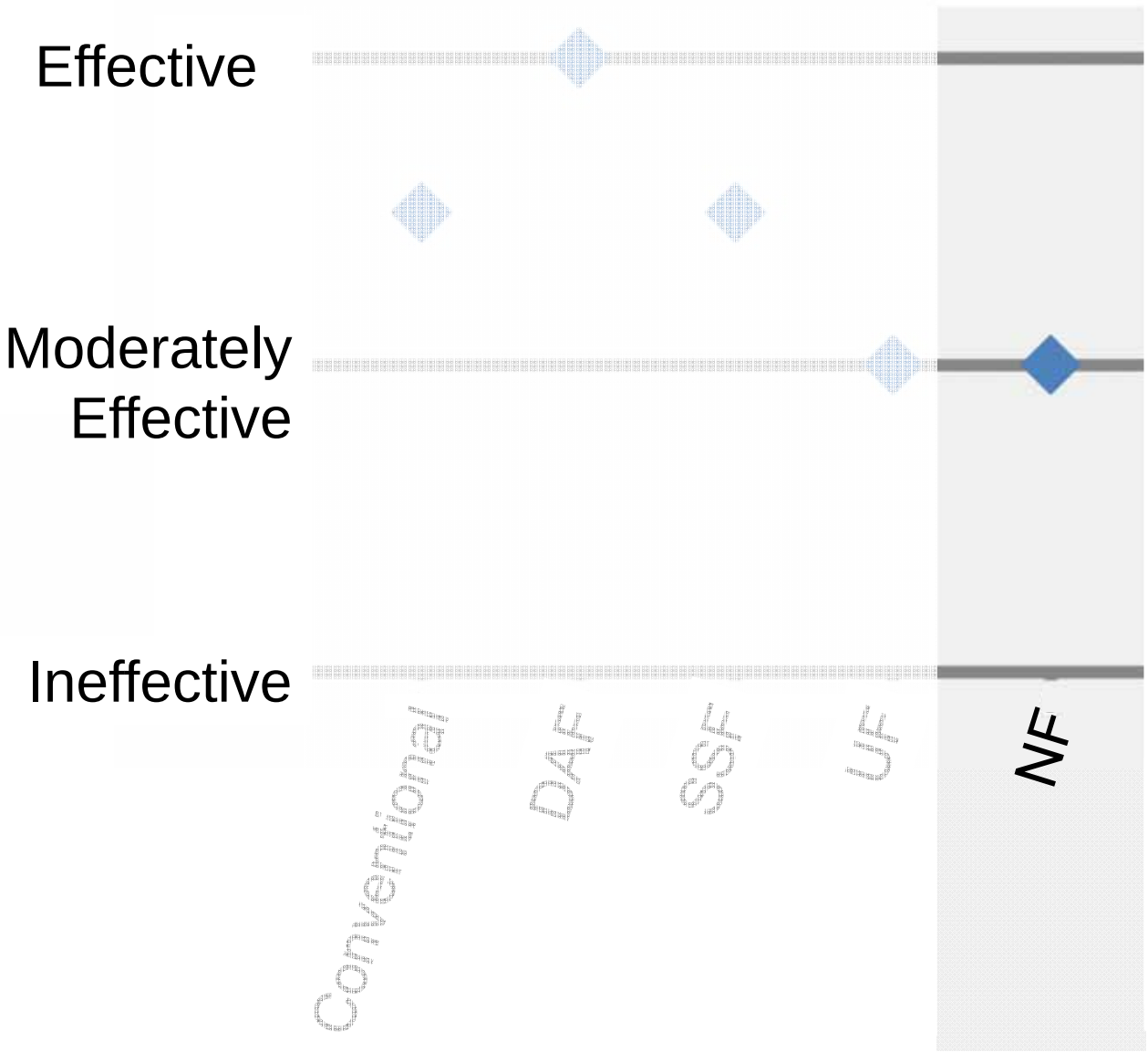


Ultrafiltration

- 90-98% removal
- Studies varied whether process ruptures cells
- May increase fouling

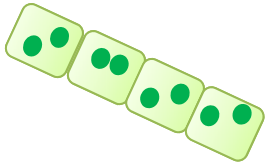
Intracellular

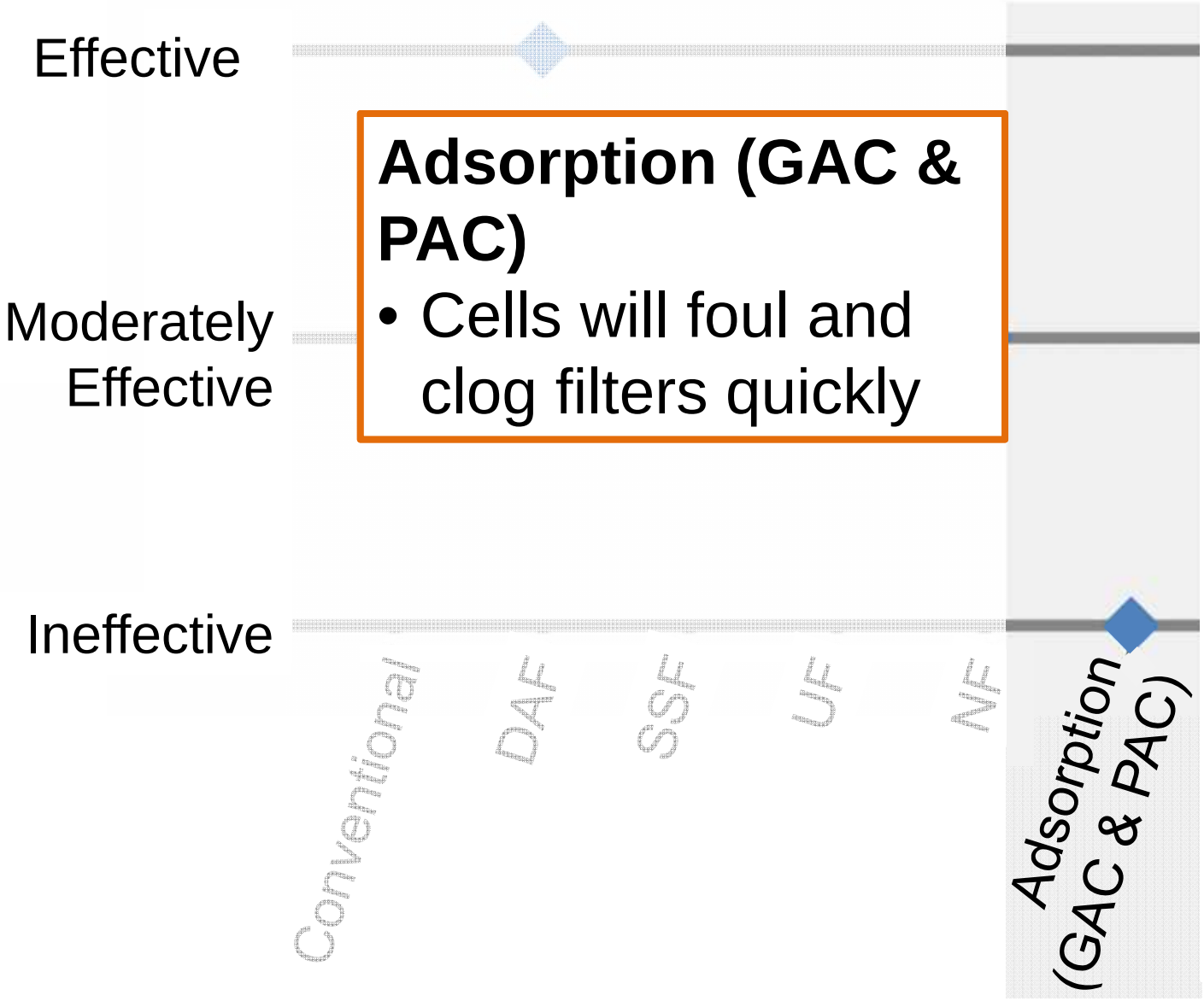




Nanofiltration
- Similar to UF

Intracellular

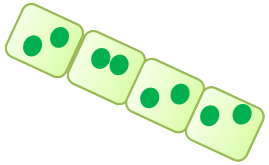


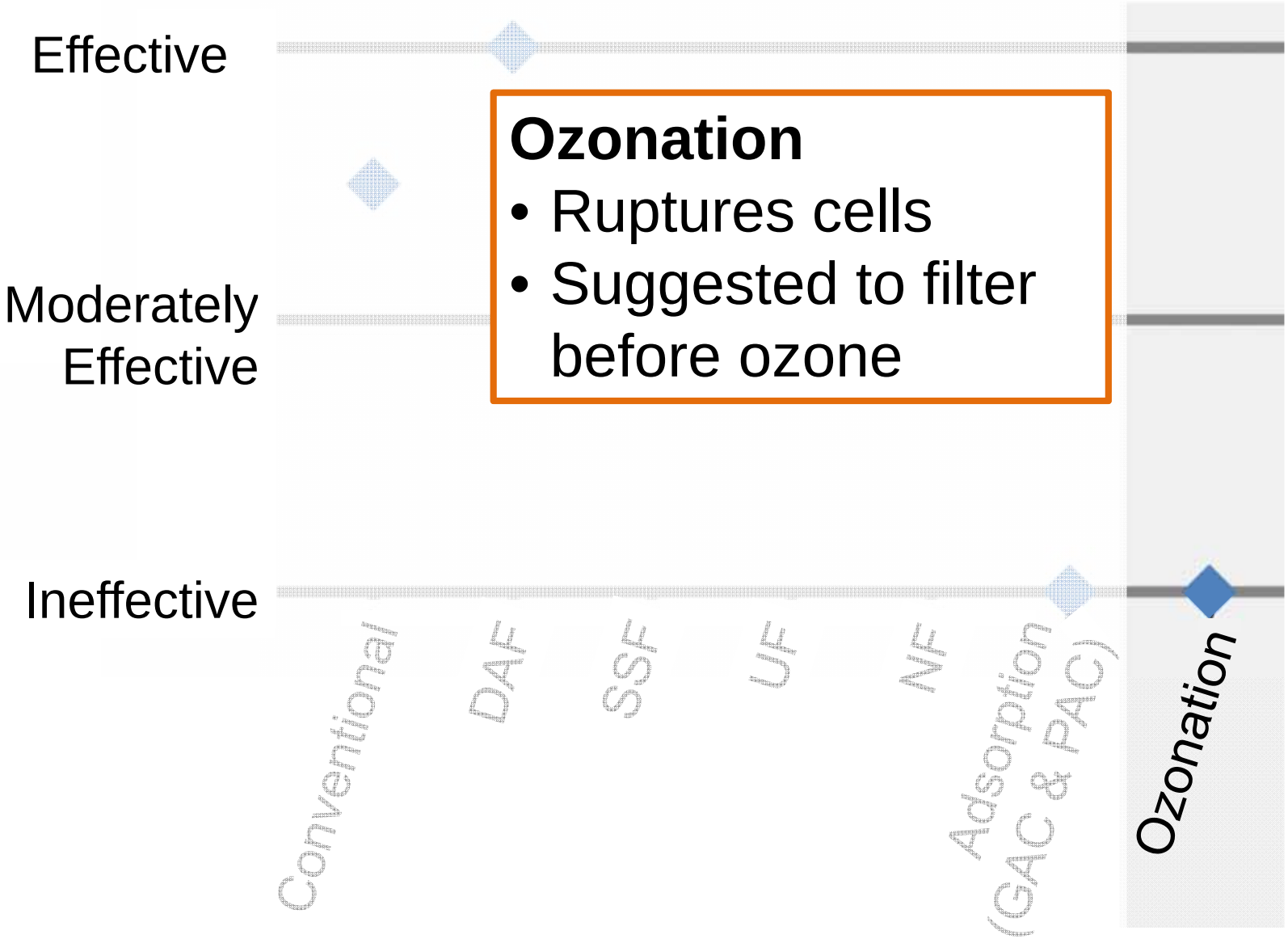


Adsorption (GAC & PAC)

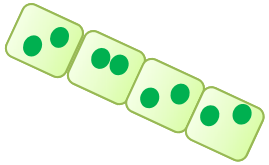
- Cells will foul and clog filters quickly

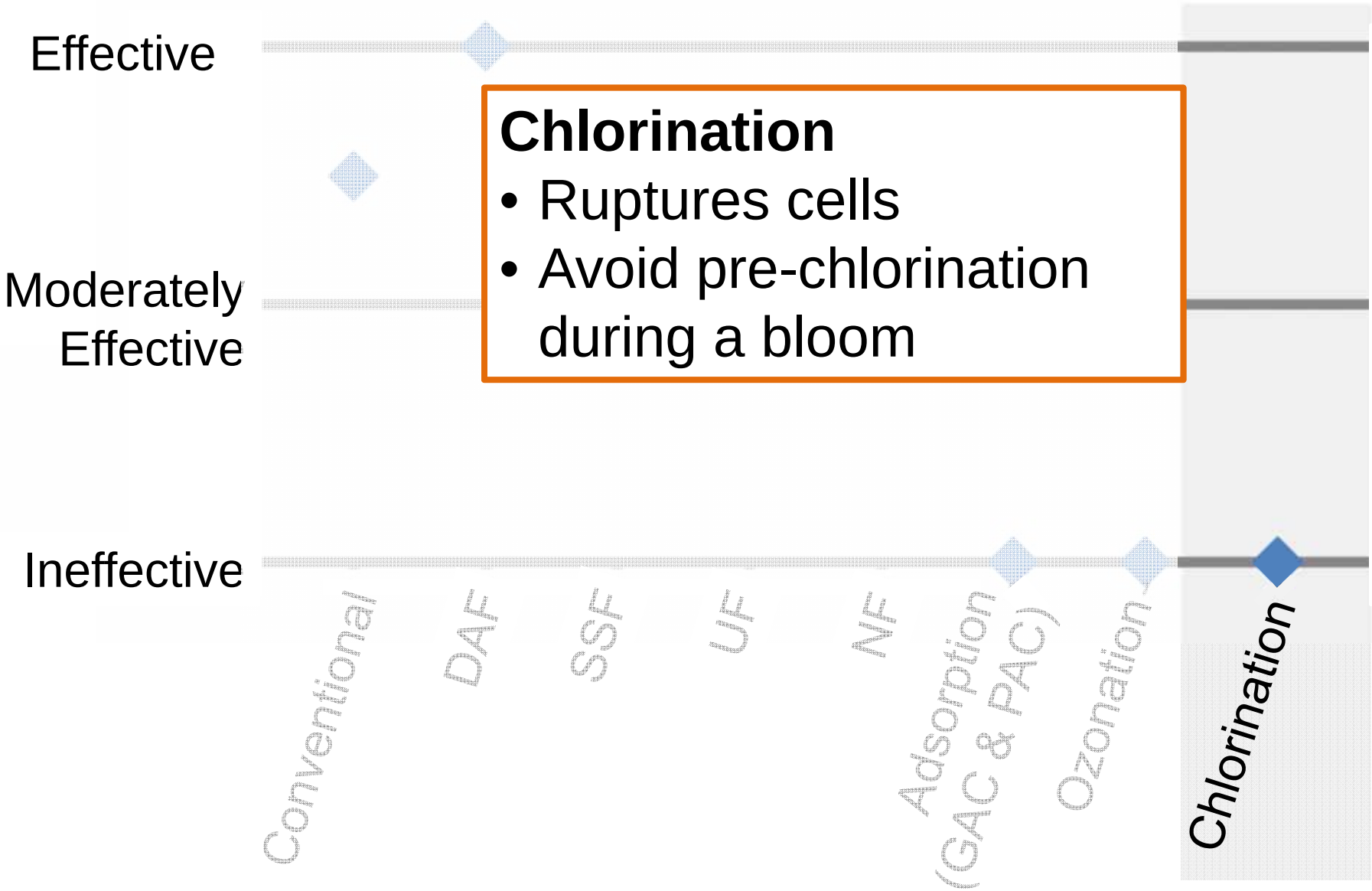
Intracellular



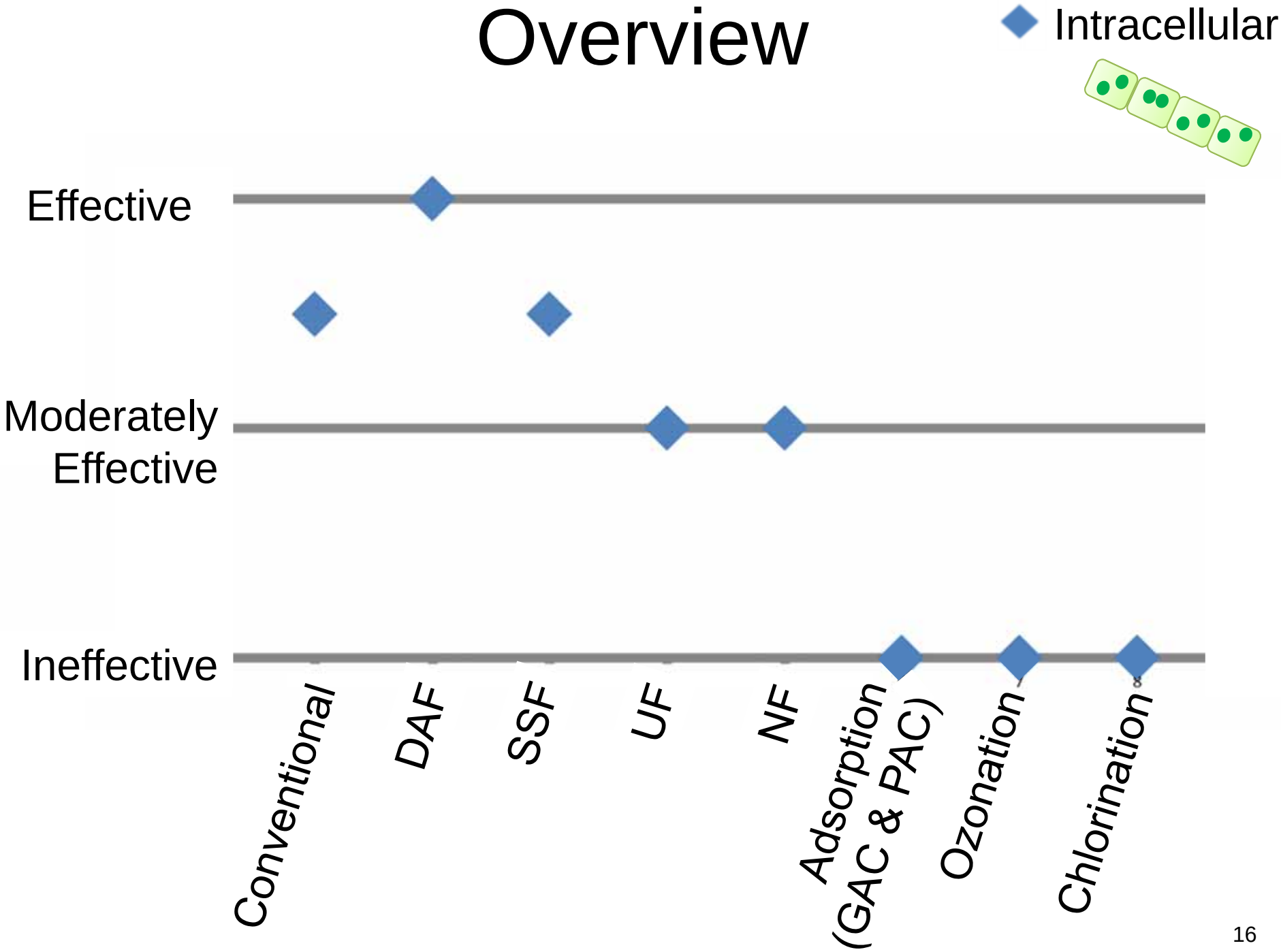


Intracellular

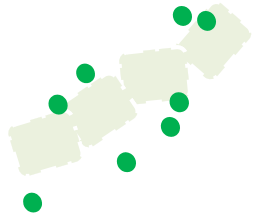


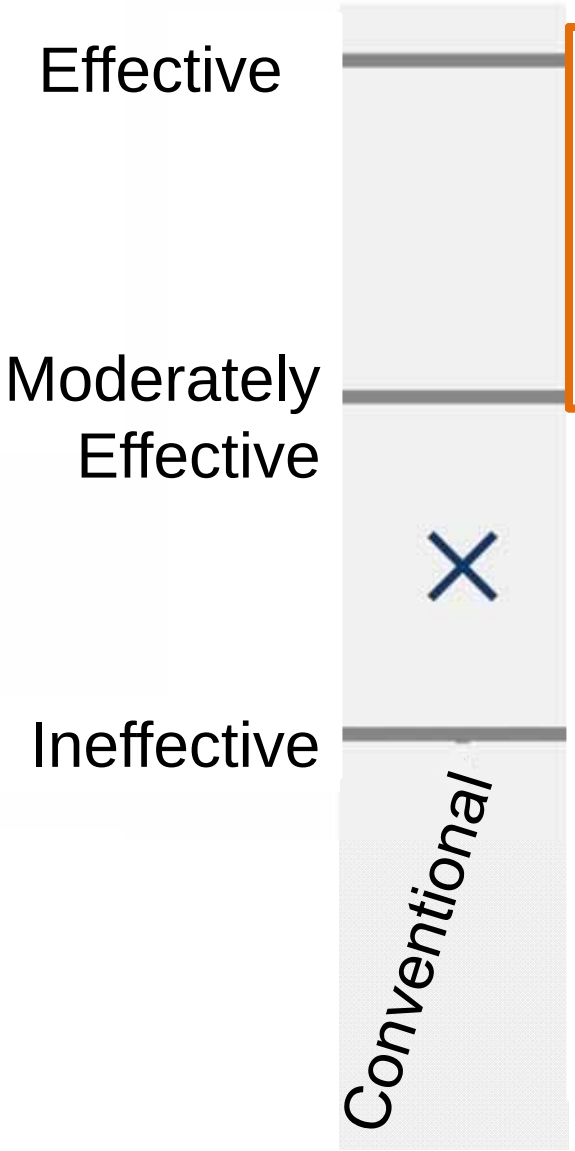


Overview


Intracellular
Effective
Moderately Effective
Ineffective
Conventional
DAF
SSF
UF
NF
Adsorption (GAC & PAC)
Ozonation
Chlorination

Extracellular

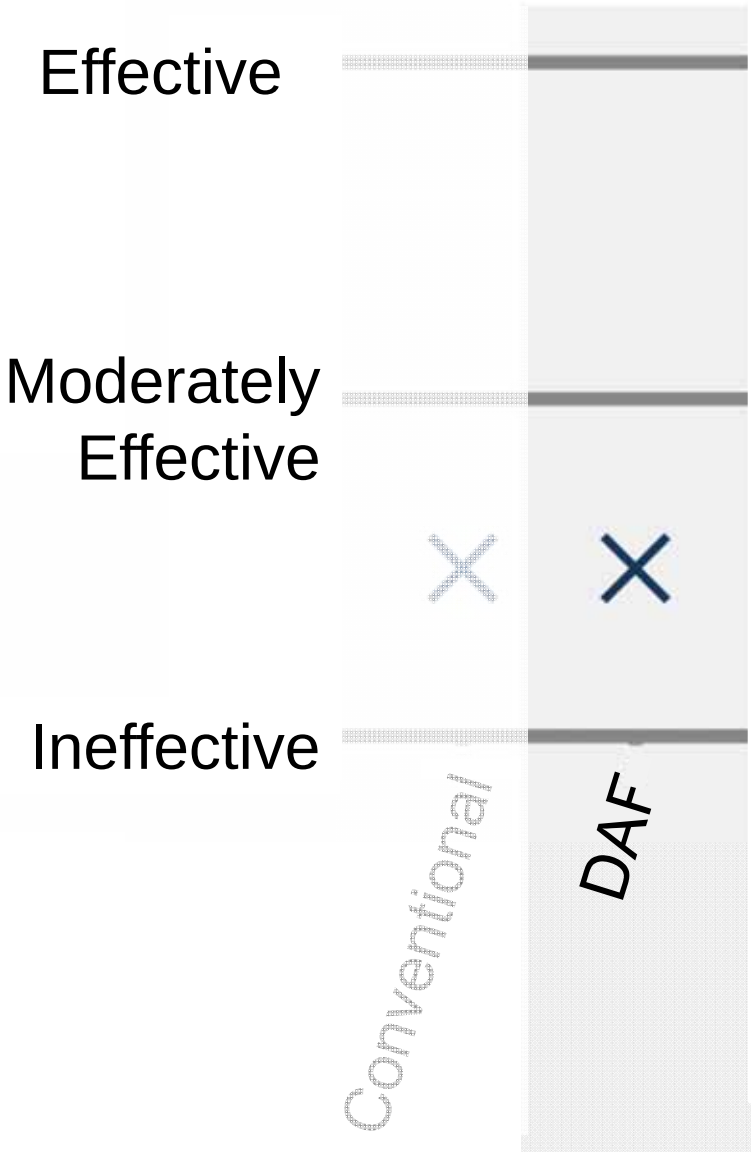




Conventional

- Inconsistent results
- MC-LR removal > AnTX-a removal
- Iron chloride > aluminum sulphate

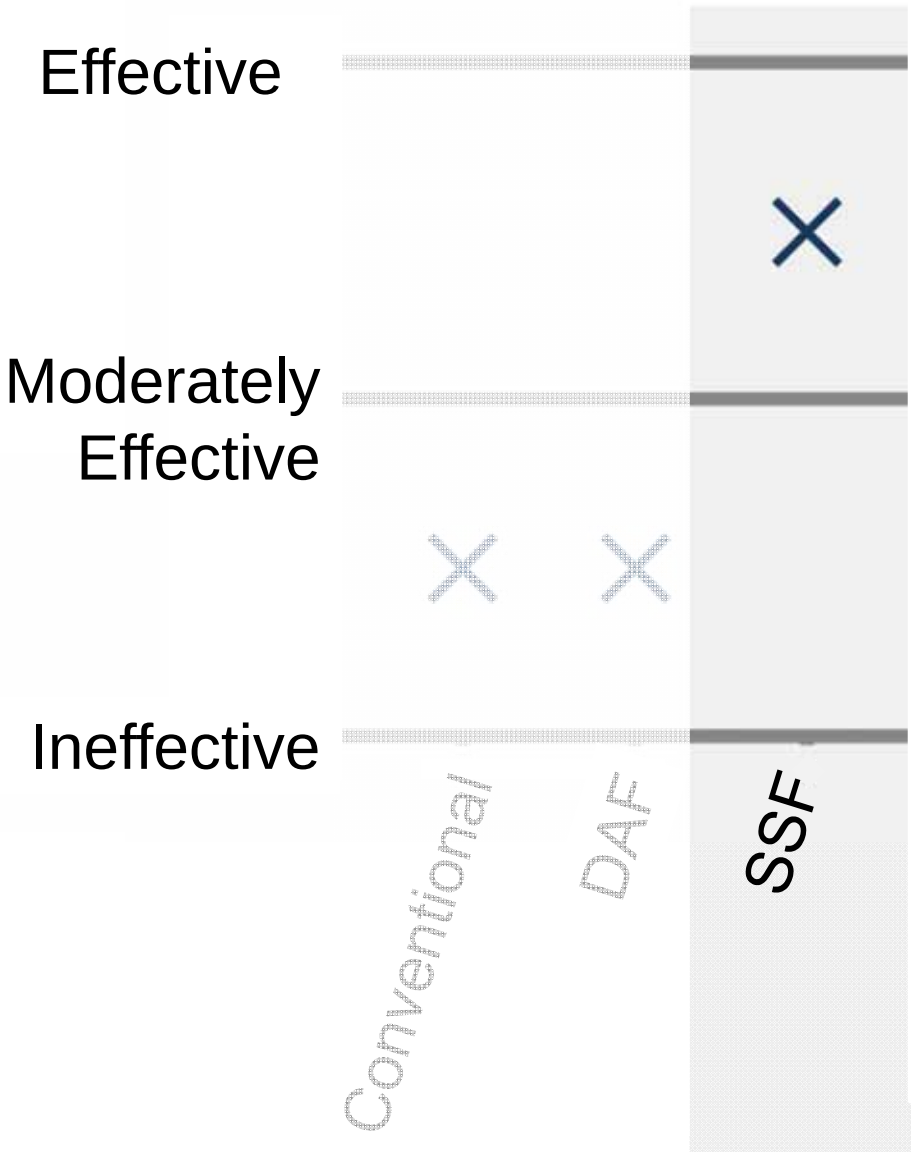
Extracellular



Dissolved Air Flotation

- Inconclusive

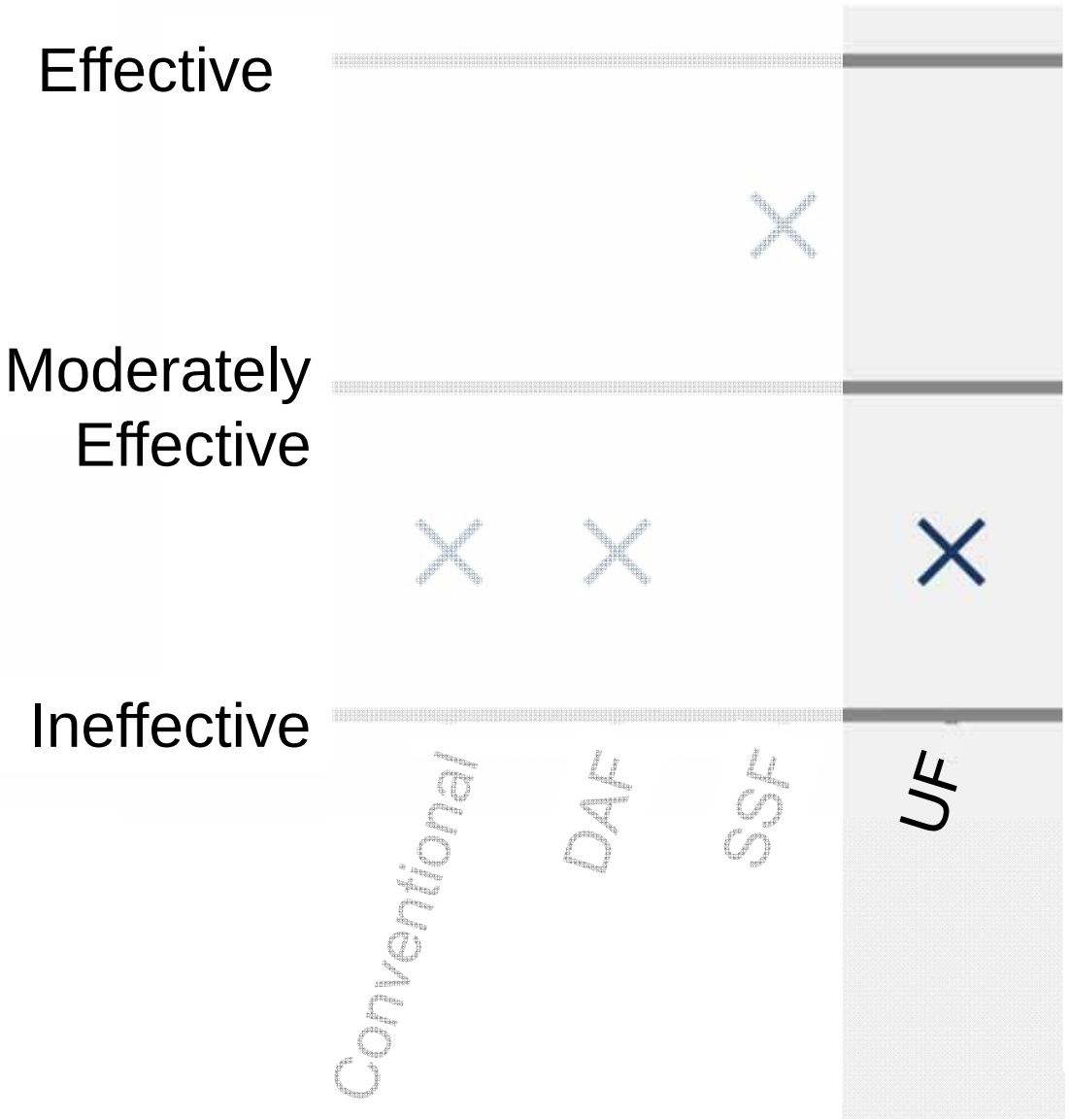
Extracellular



Slow Sand Filtration

- 80-95% MCs removed
- 70% AnTX-a removed
- Vulnerable between maintenance and at low temperatures

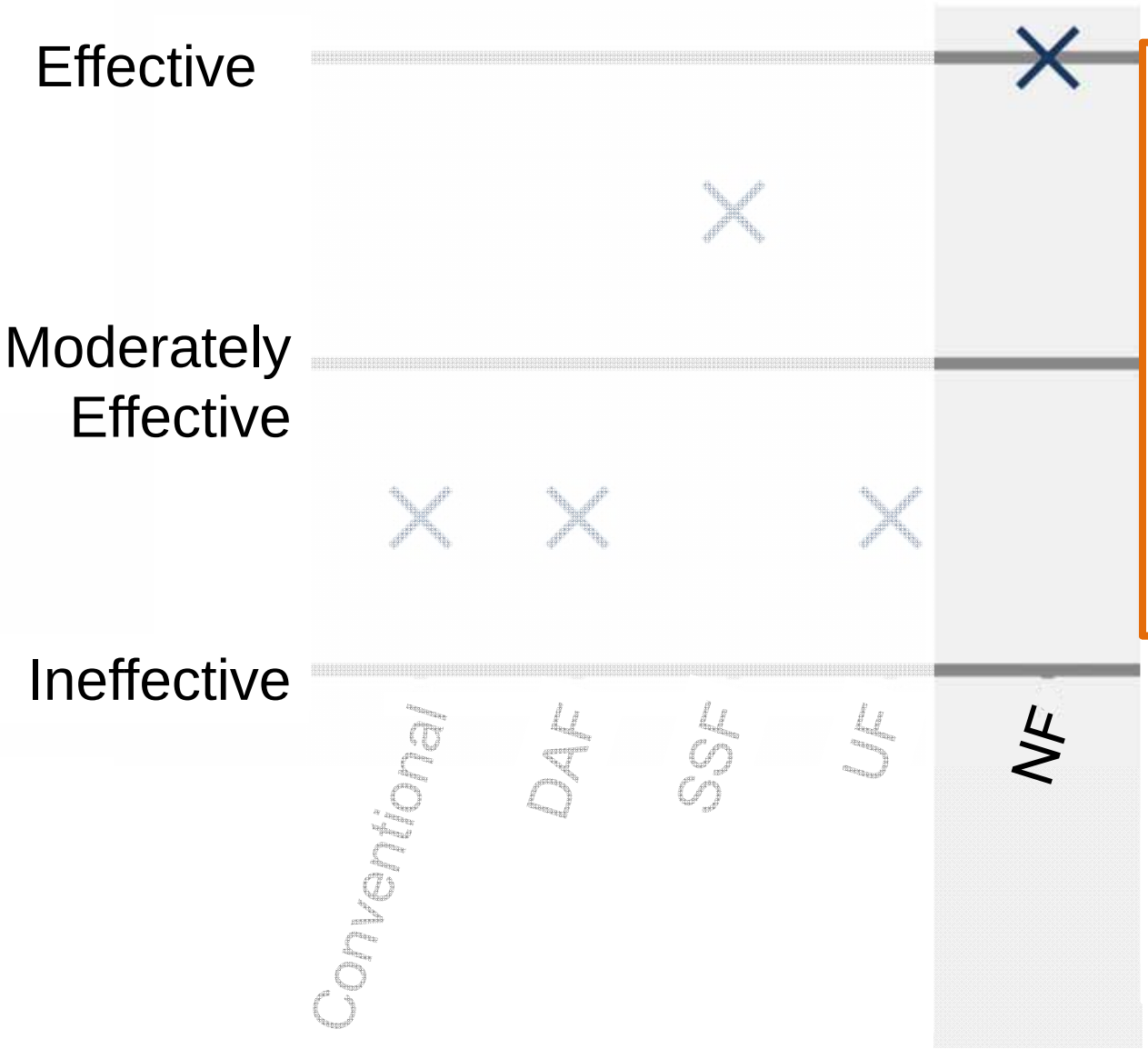
Extracellular



Ultrafiltration

- Ineffective due to pore size exclusion

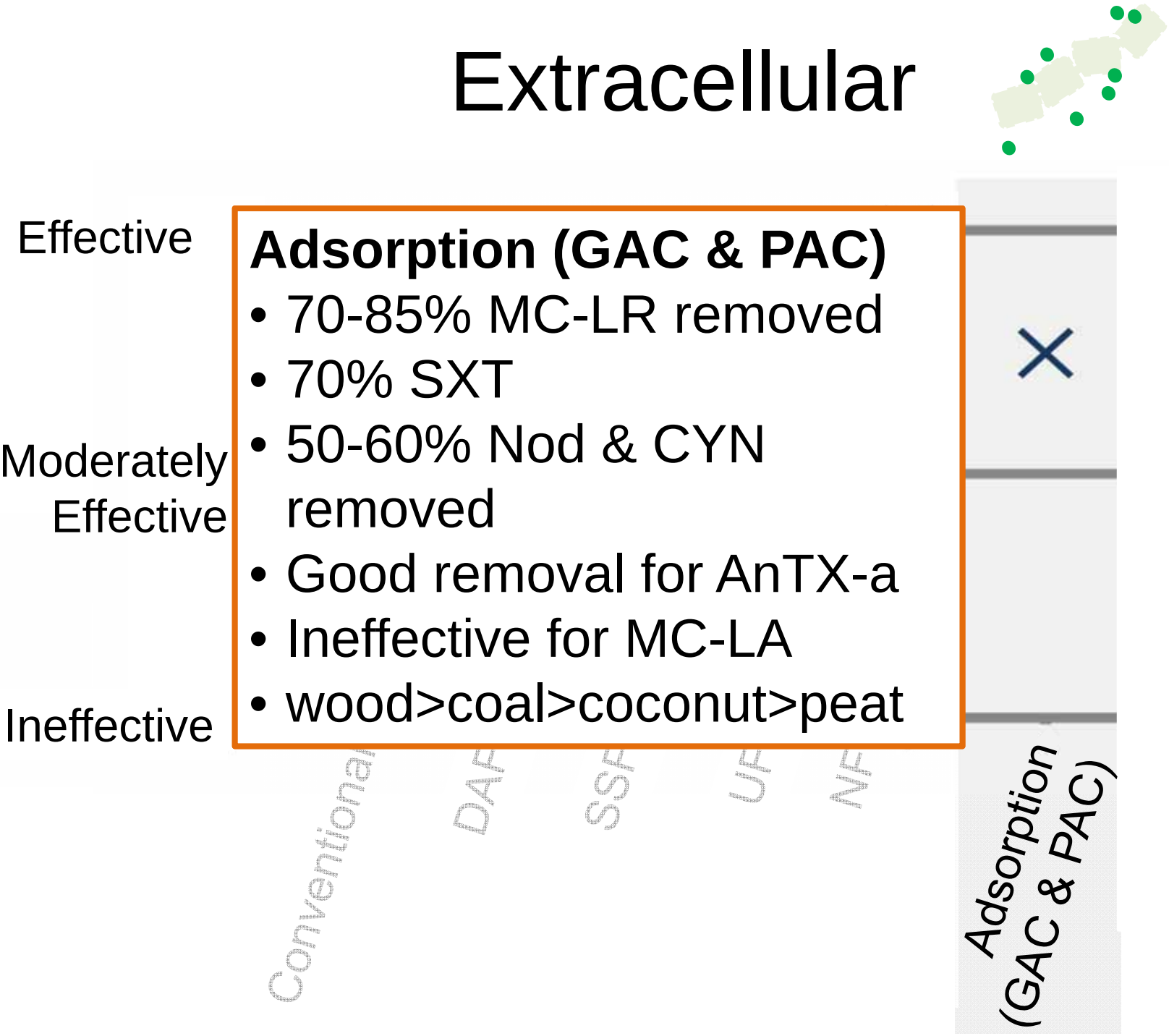
Extracellular



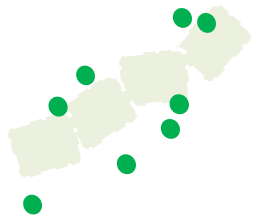
Nanofiltration

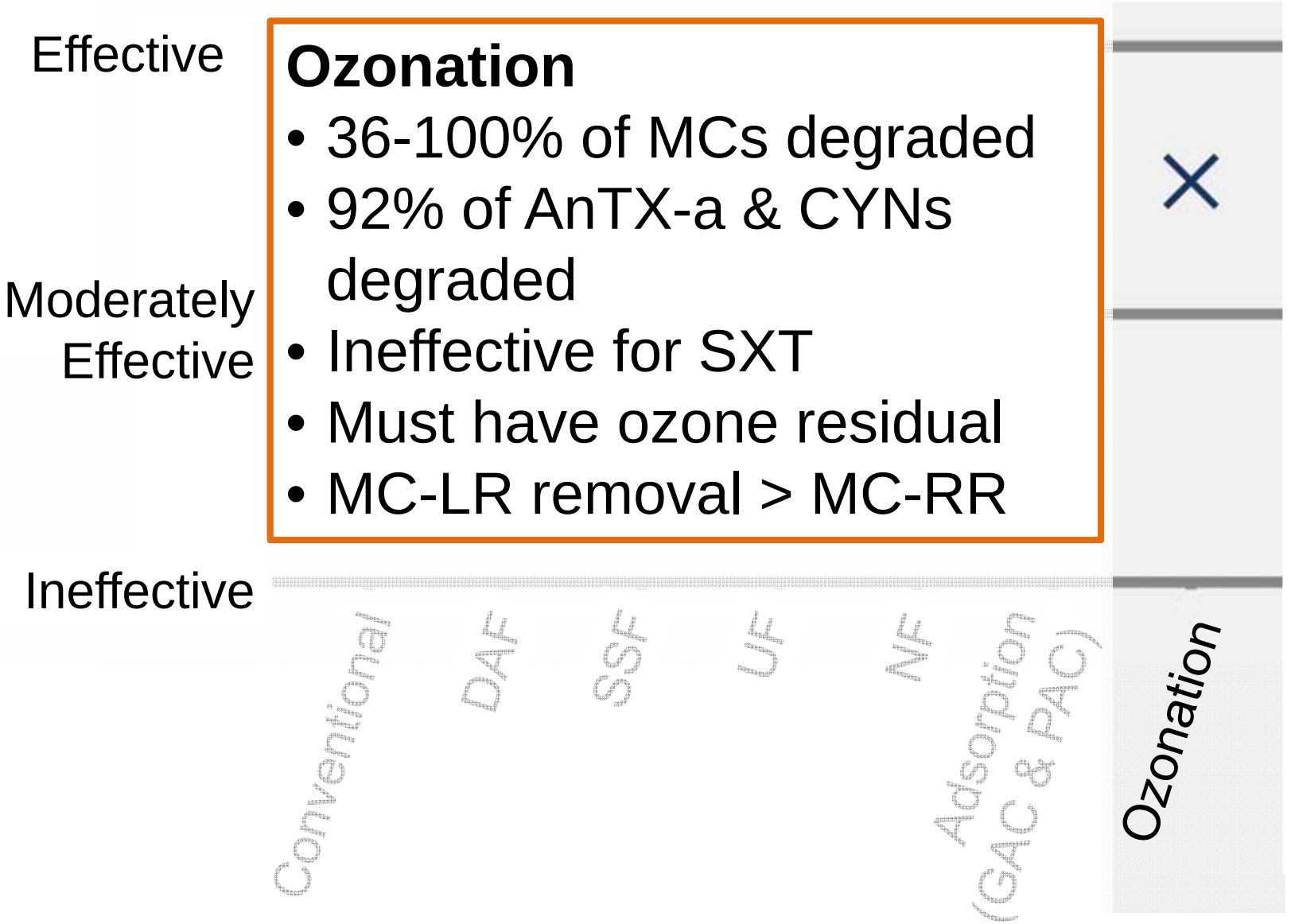
- 90-100% MCs, AnTX-a & CYN removed
- Depends on hydrophobicity and net charge

Extracellular

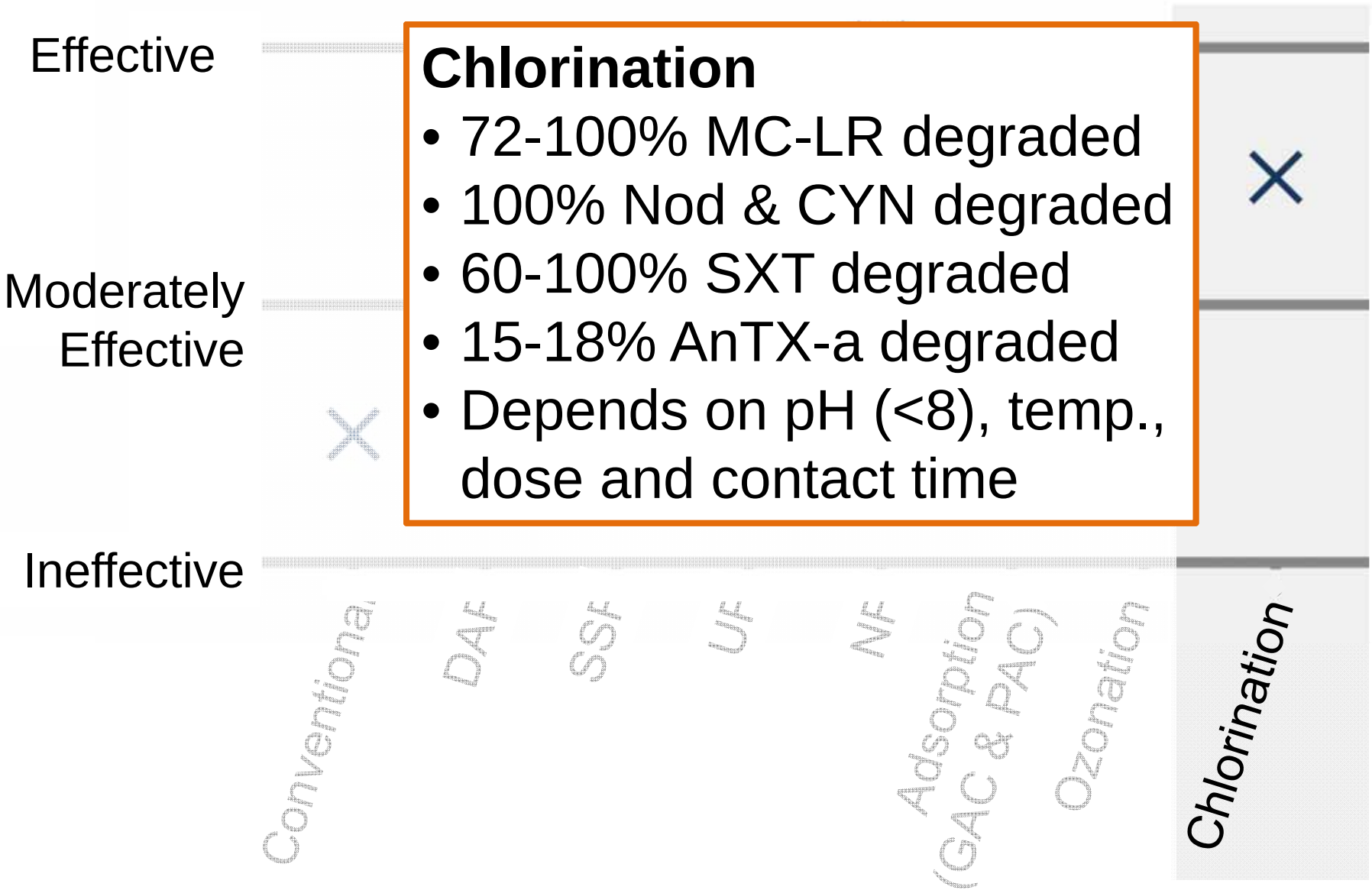


Extracellular

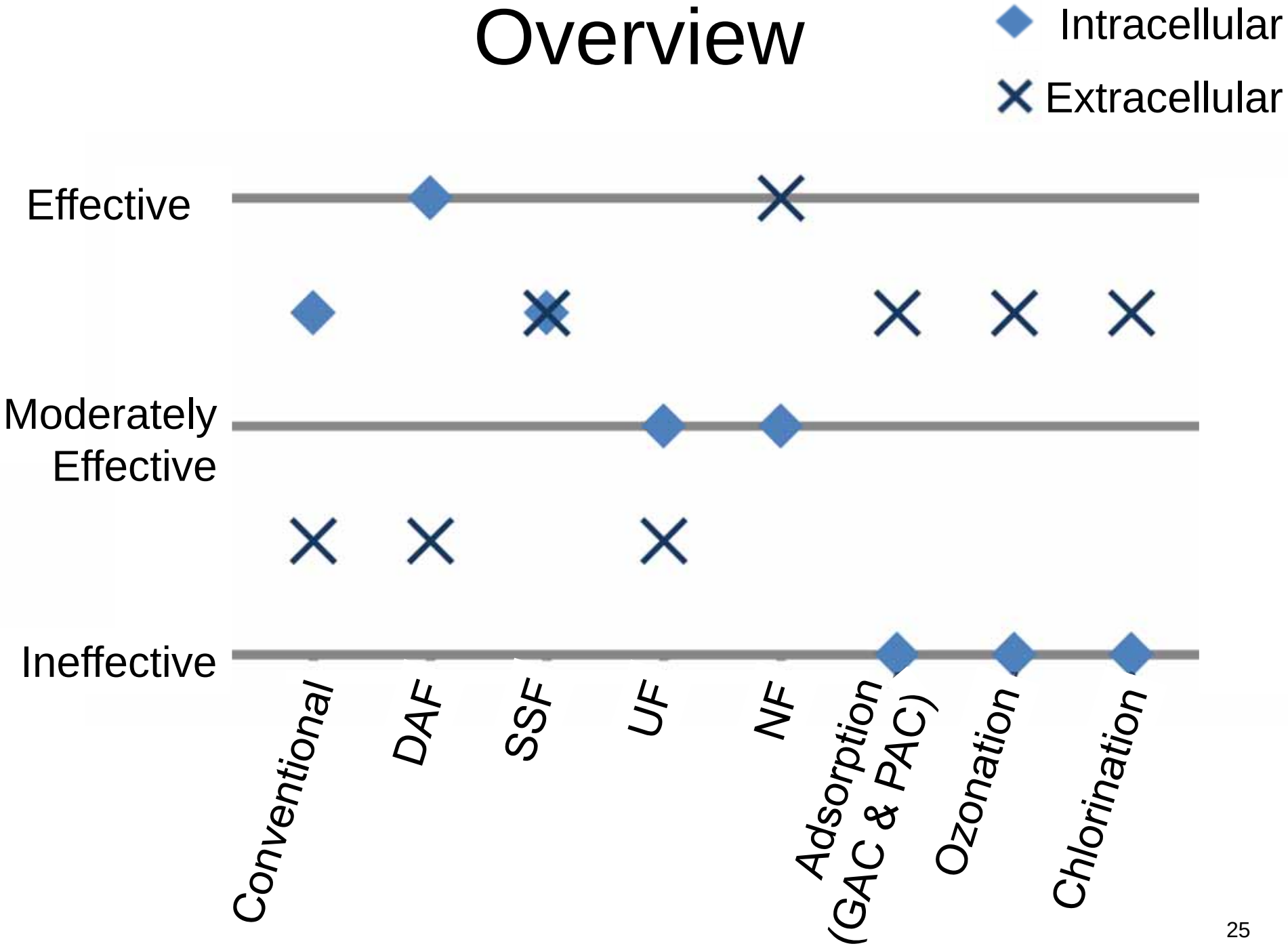




Extracellular



Overview


Intracellular
Extracellular
Effective
Moderately Effective
Ineffective
Conventional
DAF
SSF
UF
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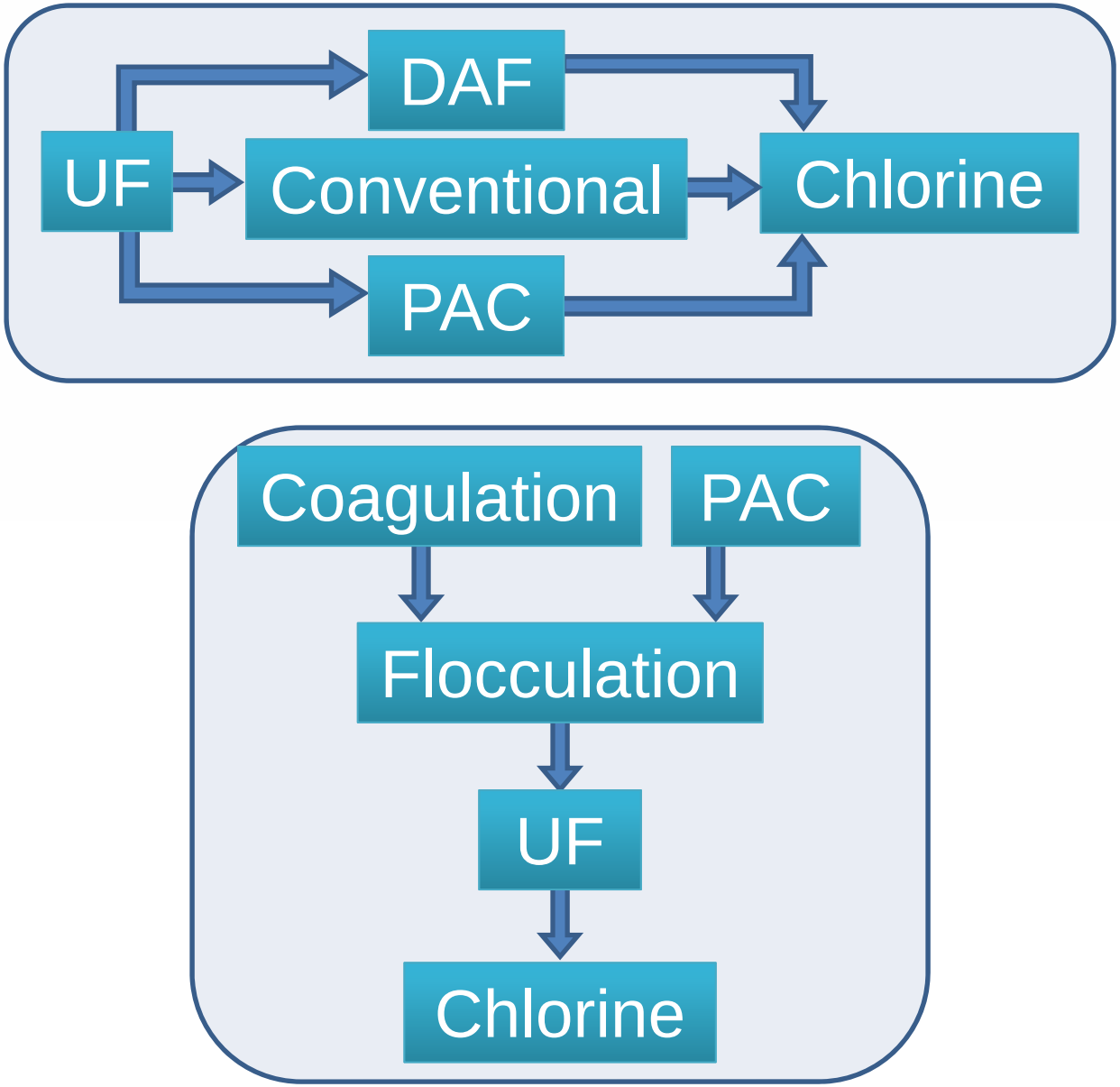
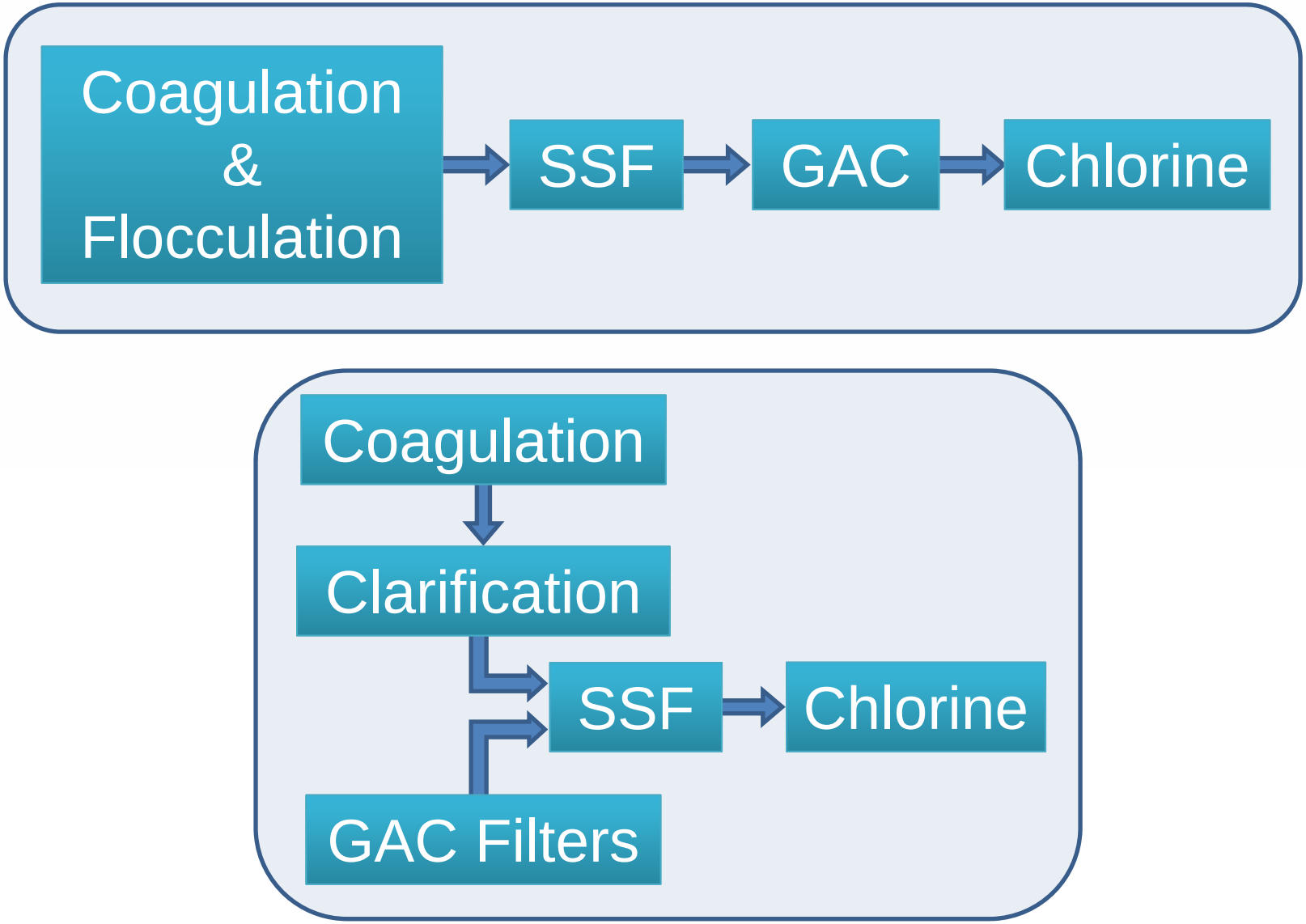
Adsorption (GAC & PAC)
Ozonation
Chlorination

Multi-barrier Approach



Multi-barrier Approach

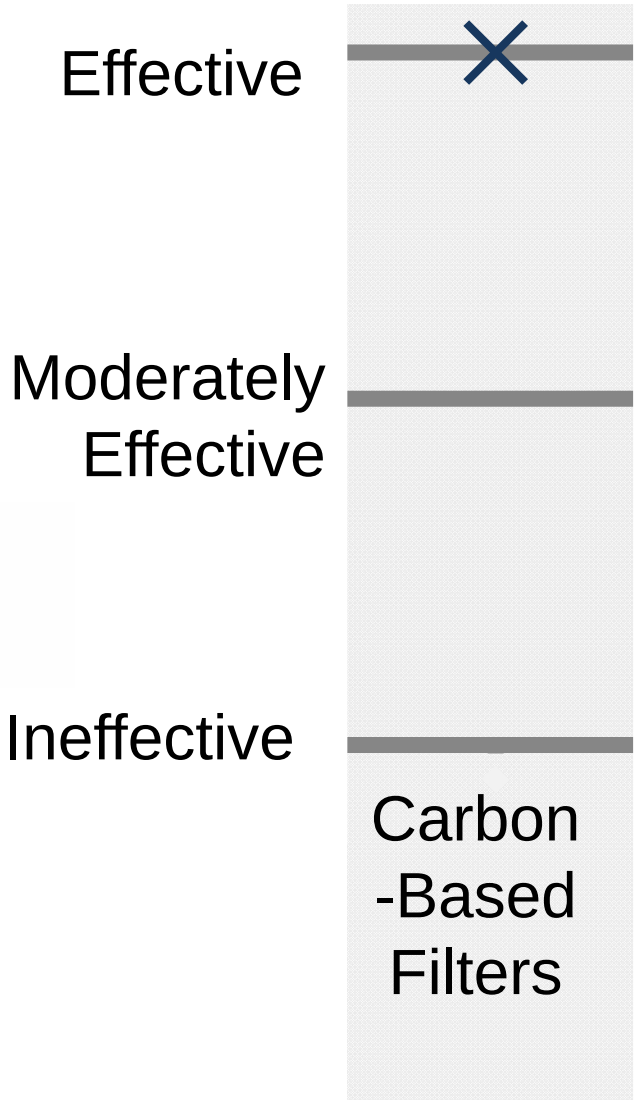


Household Treatment

- Cartridge Filters
- Reverse Osmosis
- Ultraviolet Treatment

Household Treatment: Microcystins only

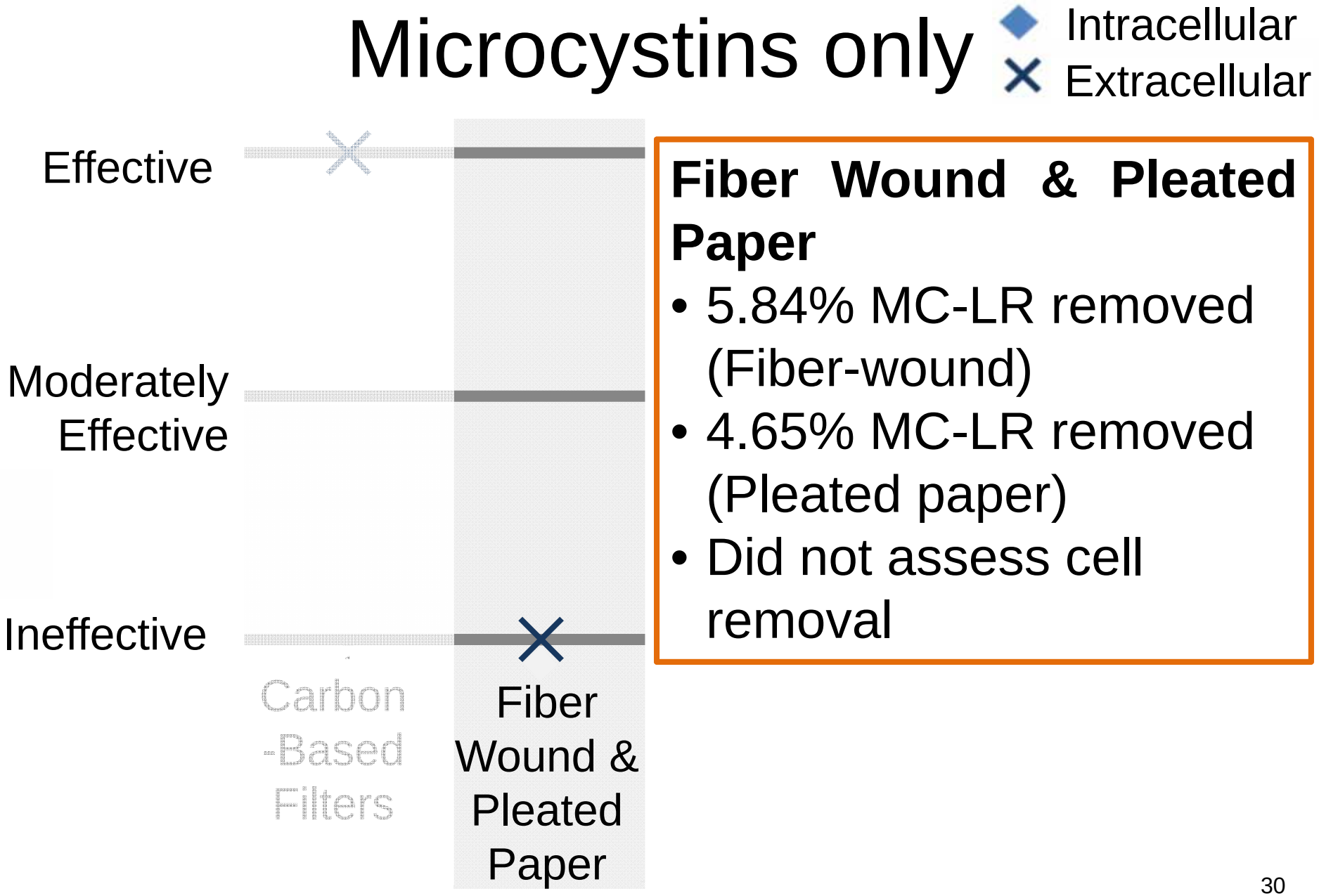
Intracellular
Extracellular



Carbon-Based Filters

- 99% MC-LR removed
- Did not assess cell removal

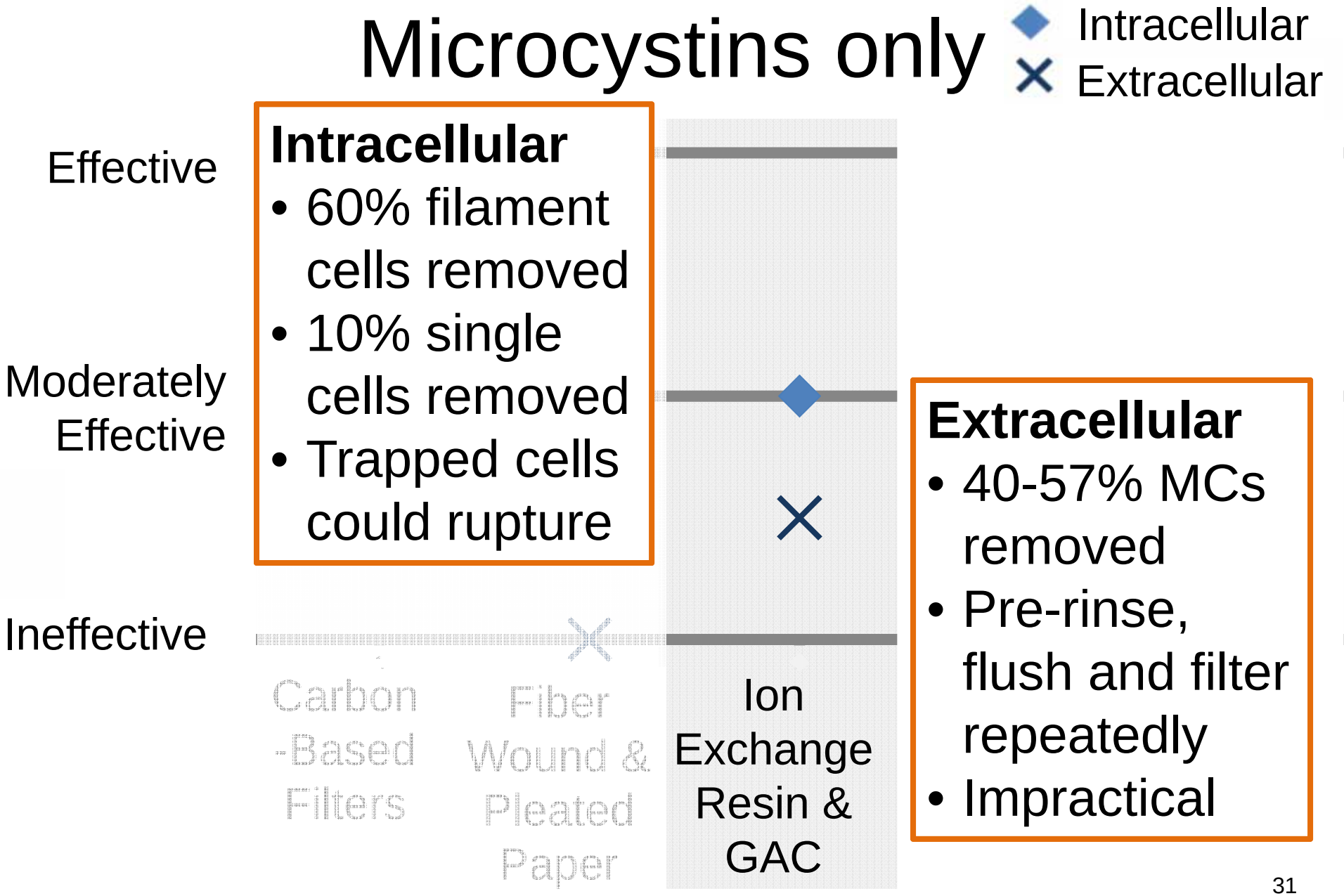
Household Treatment: Microcystins only



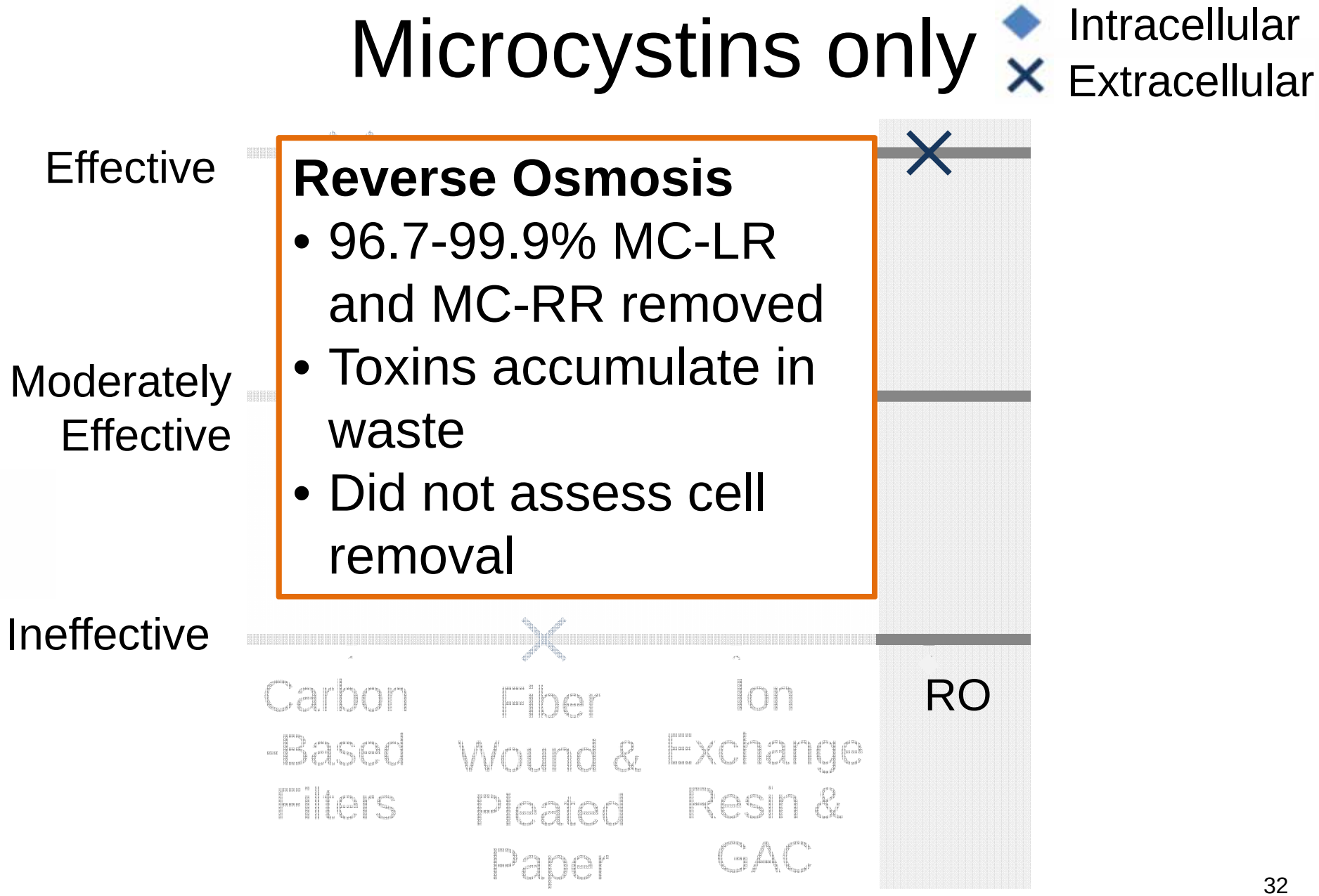
Fiber Wound & Pleated Paper

- 5.84% MC-LR removed (Fiber-wound)
- 4.65% MC-LR removed (Pleated paper)
- Did not assess cell removal

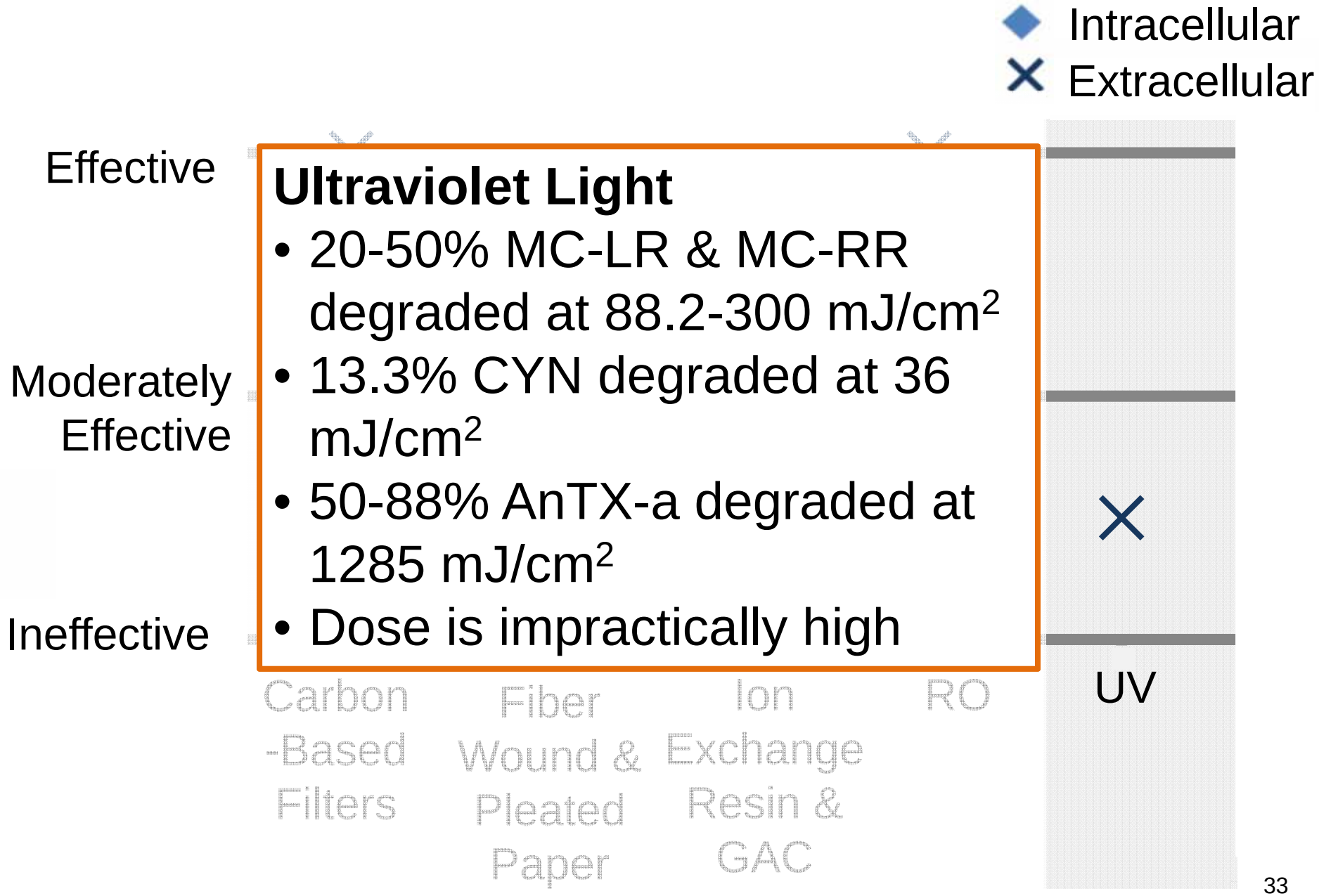
Household Treatment: Microcystins only



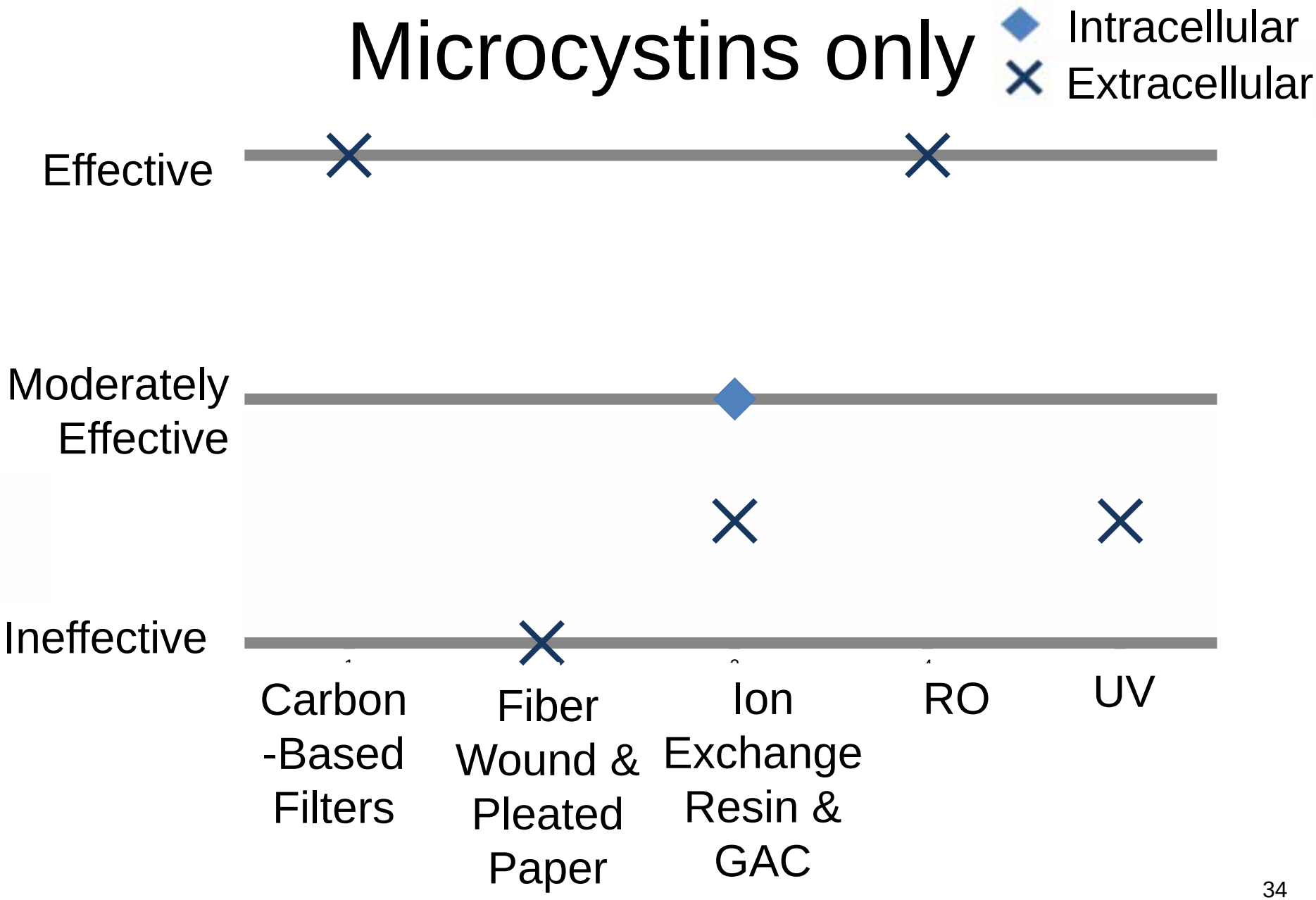
Household Treatment: Microcystins only



Household Treatment



Household Treatment: Microcystins only



Research gaps

- Study other variants, particularly for household units
- Long-term pilot-scale tests and full-scale tests
- Periodic exposures of cyanotoxins to treatment studies
- Further research & development for household treatment removal efficiencies
- Other treatments: AOP, Biofiltration, etc.

Conclusion

- Knowledge gap in household treatment units for cyanotoxin removal
- Technologies for large and small water plants
  - Intracellular toxins: Conventional, DAF, SSF
  - Extracellular toxins: SSF, NF, AC, Ozone, Chlorine
- Multi-barrier approach add resilience

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Thank you for your attention!

Questions?

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