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Microbial Risk Management for Atmospheric Condensate Collections

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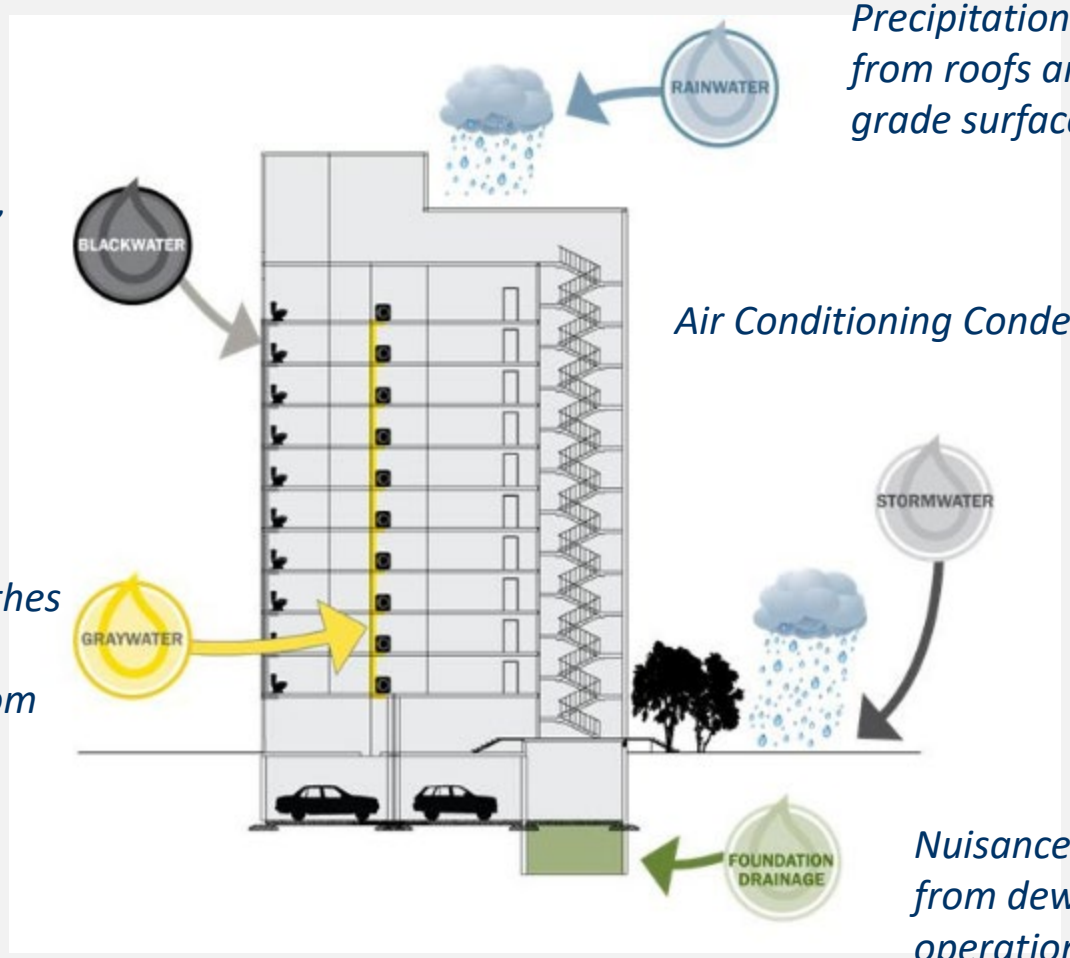
Motivation: Onsite Water Sources

Precipitation collected from roofs and above-grade surfaces

Wastewater from toilets, dishwashers, kitchen sinks, and utility sinks



Air Conditioning Condensate

Precipitation collected at or below grade

Wastewater from clothes washers, bathtubs, showers, and bathroom sinks

Nuisance groundwater from dewatering operations

Motivation: Onsite Water Sources

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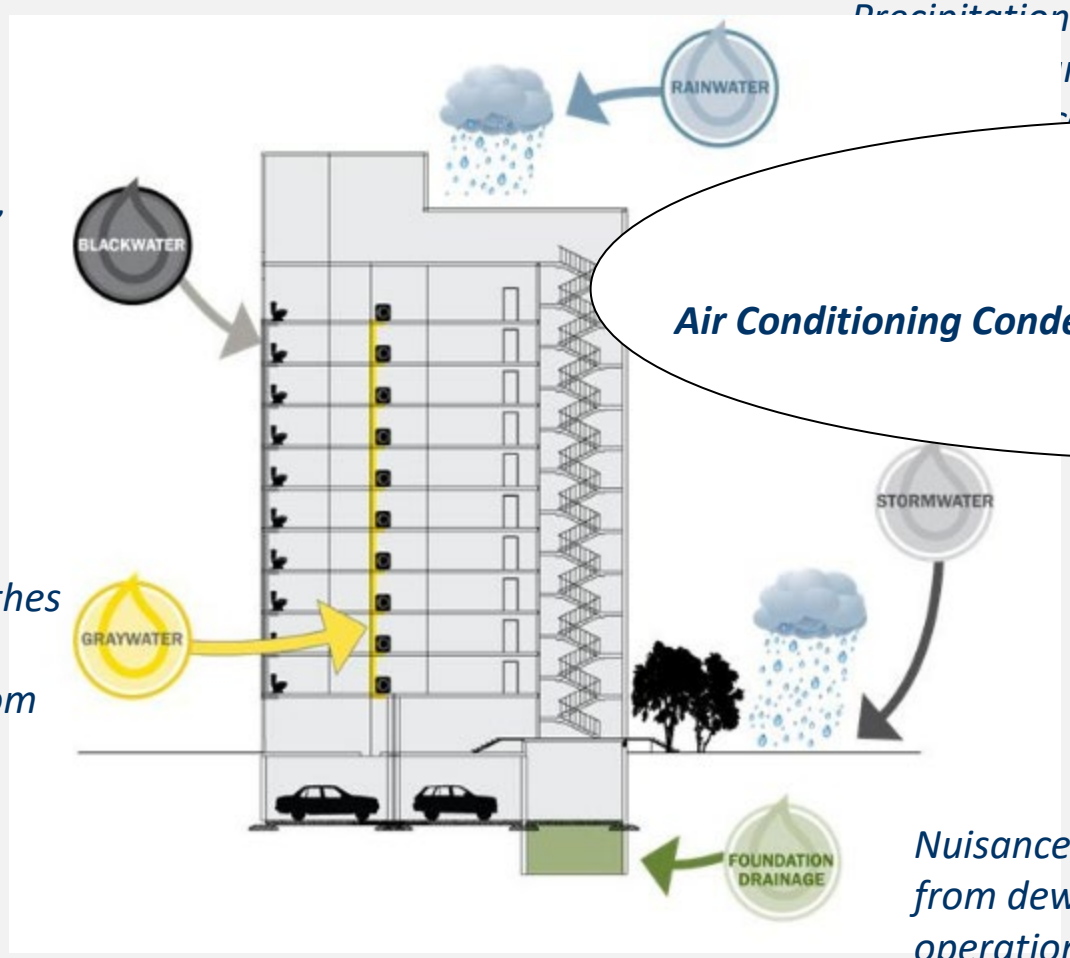

Precipitation collected and above-

Air Conditioning Condensate

Atmospheric Water Harvesting / Generation (AWG)

Precipitation collected at or below grade

Nuisance groundwater from dewatering operations

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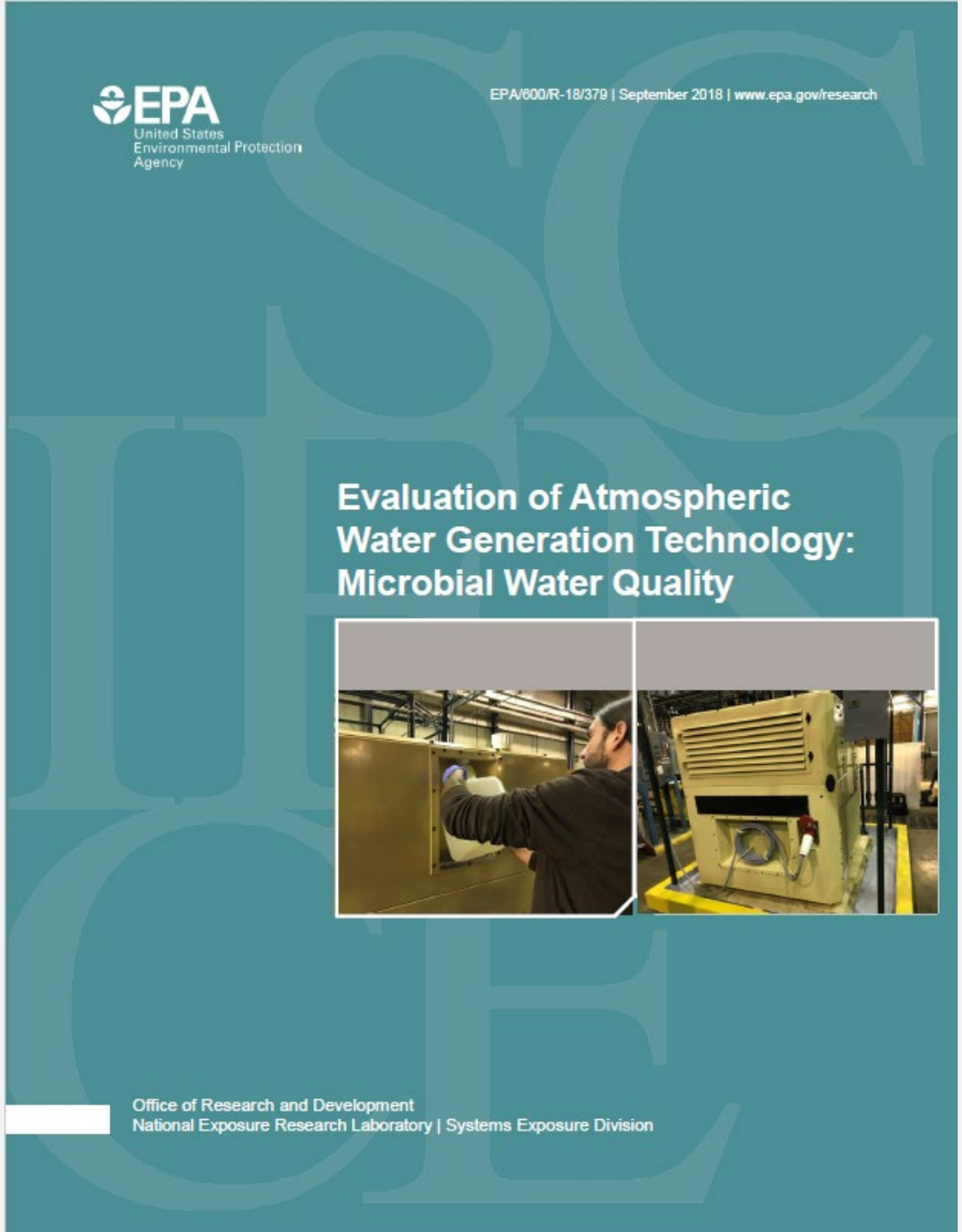

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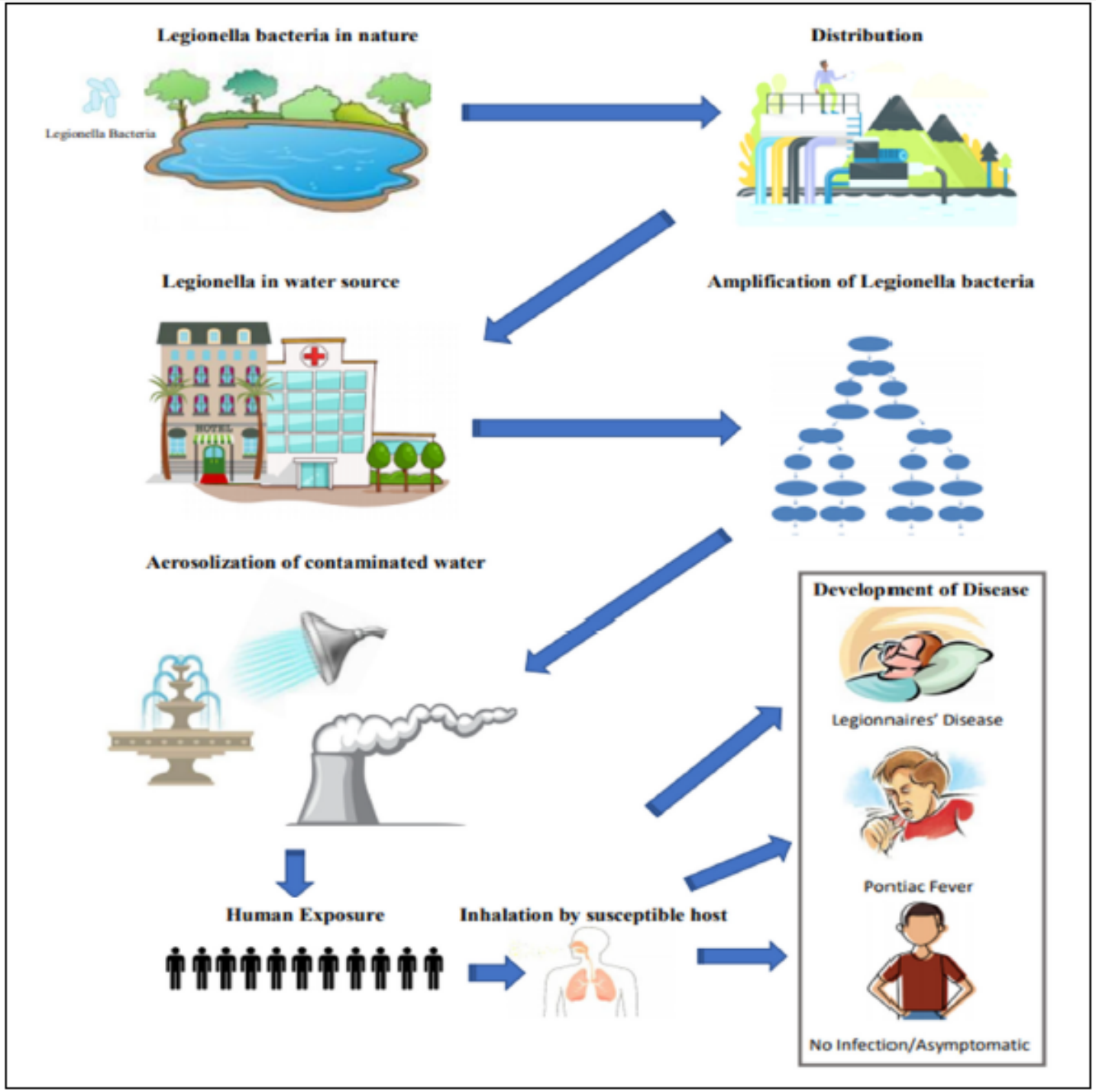
Water Quality Considerations

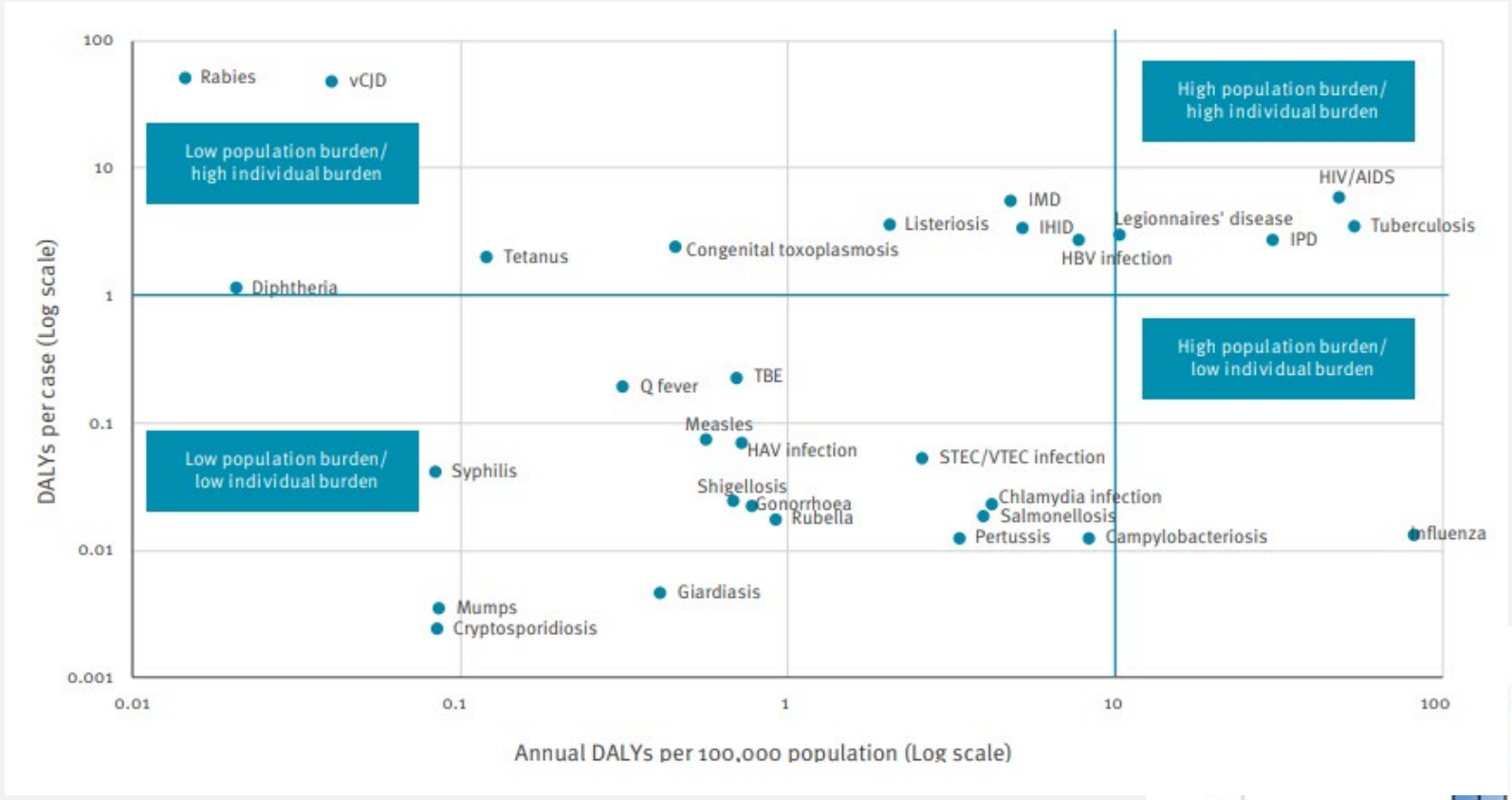
- Chemical risks:
  - Organics, ions, and particulates in source air or from system components
  - Some controlled by air filtration, some by water treatment
  - Maximum contaminant levels (MCLs) available for drinking water
  - *Not emphasized in current presentation*
- Microbial risks:
  - Unlike traditional source waters, fecal pathogens are not the primary concern
  - Growth of opportunistic environmental pathogens is common to all water systems
  - Regulatory approach linked to source water (*i.e.*, surface or ground)
  - *Subject of current presentation*

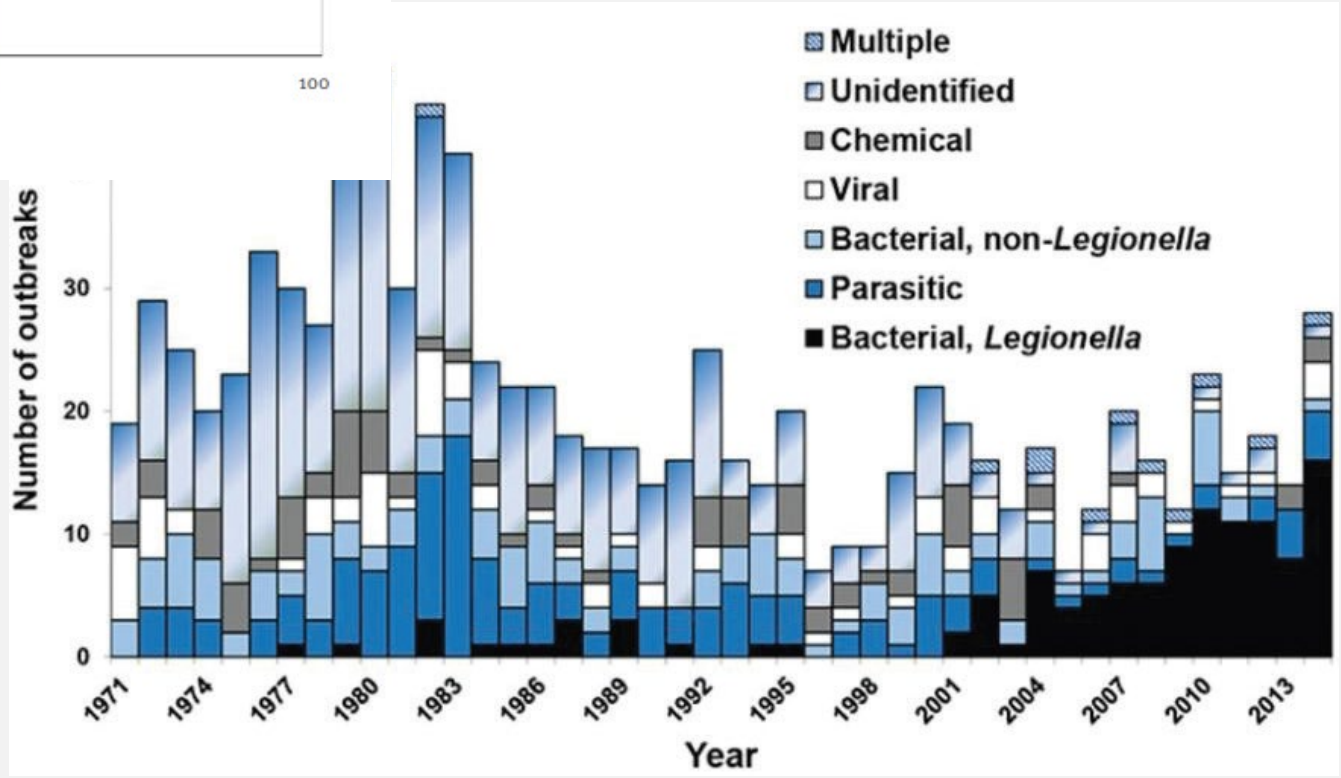
Legionella – waterborne pathway to disease



AIHA (2022) Recognition, Evaluation, and Control of Legionella in Building Water Systems

Legionella in water systems – high health burden

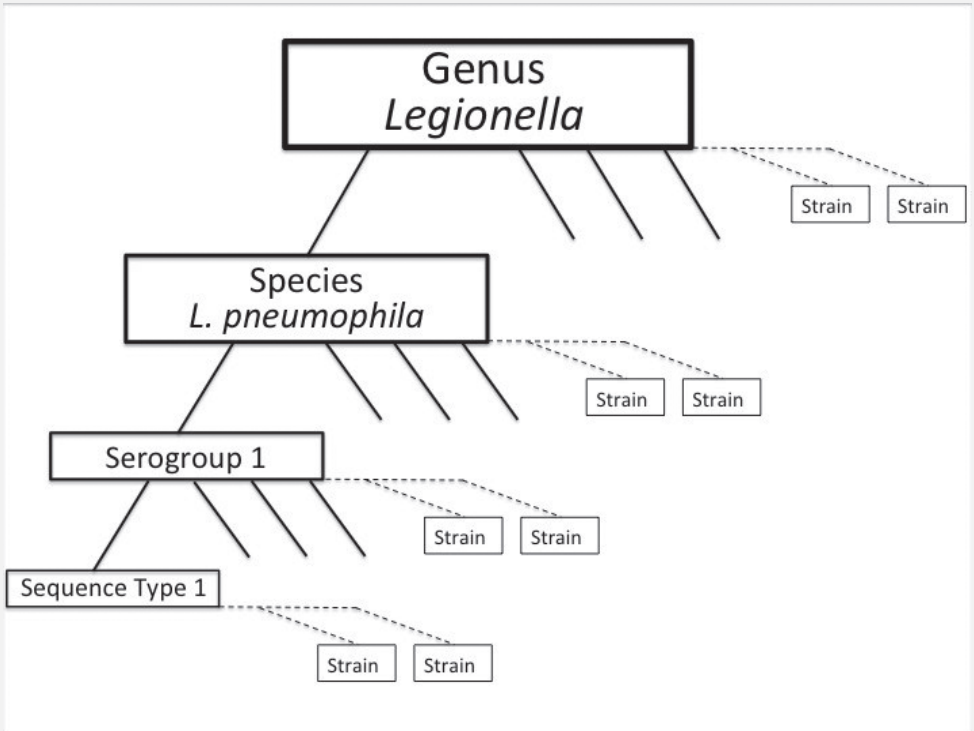




NAS (2020) Management of Legionella in Water Systems

Microbial Testing Targets

- Direct testing of opportunistic pathogens
  - *Legionella, Mycobacterium* in this study
  - Culture vs. molecular ("PCR")
- Heterotopic plate counts (HPC)
  - *"HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is."*
- Gene sequencing of microbial community



NAS (2020) Management of Legionella in Water Systems

https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

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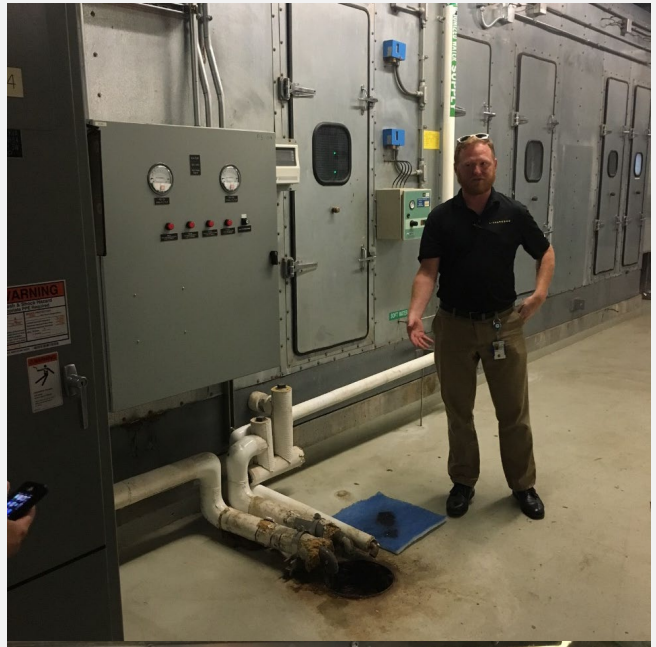
Regulatory Context

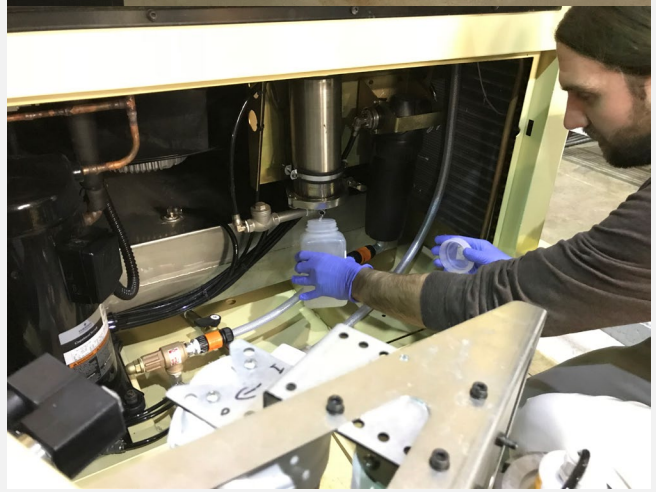
- *"A **public water system** provides water for human consumption through pipes or other constructed conveyances to at least 15 service connections or **serves an average of at least 25 people for at least 60 days a year**."*
- Most microbial contaminants controlled by "Treatment Technique" – disinfection and filtration (if needed) **under Surface Water Treatment Rule**
  - *"Legionella: No limit, but EPA believes that if Giardia and viruses are removed/inactivated, according to the treatment techniques in the Surface Water Treatment Rule, Legionella will also be controlled."*
  - *"Heterotrophic Plate Count (HPC): No more than 500 bacterial colonies per milliliter."*
- *Legionella* Maximum Contaminant Level Goal (**MCLG**) **= Zero**

https://www.epa.gov/dwreginfo/information-about-public-water-systems
https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

This Study: AWG and AC Condensates

- AWG: One system, raw and post-treatment waters
  - Sediment filter, carbon filter, UV disinfection, mineralization, polish filtration
  - Periodic recirculation of collected water
  - Routine operation and maintenance
  - Weekly sampling; 22 samples
- Air conditioning (AC): Four locations, 13 systems
  - Various levels of reuse (current, planned, none)
  - Biweekly to monthly sampling; 82 samples
  - Additional 36 biofilm samples from coils, pipes, and drains





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Results: Opportunistic Pathogens in AWG

	Collection Date	*M. avium*	*M. intracellulare*	*L. pneumophila* serogroup 1
Raw Water	3/14/2018	BLQ[1]	BLQ	BLQ
	3/21/2018	BLQ	BLQ	BLQ
	3/29/2018	BLQ	BLQ	BLQ
	4/18/2018	BLQ	BLQ	BLQ
	4/26/2018	BLQ	BLQ	BLQ
	5/17/2018	BLQ	BLQ	BLQ
	5/24/2018	BLQ	BLQ	BLQ
	5/30/2018	BLQ	BLQ	BLQ
Treated Water	3/14/2018	BLQ	BLQ	BLQ
	3/21/2018	BLQ	BLQ	BLQ
	3/29/2018	BLQ	BLQ	BLQ
	4/5/2018	BLQ	BLQ	BLQ
	4/18/2018	BLQ	BLQ	BLQ
	4/26/2018	BLQ	BLQ	BLQ
	5/2/2018	Undetermined	Undetermined	Undetermined
	5/17/2018	Undetermined	Undetermined	Undetermined
	5/24/2018	Undetermined	Undetermined	Undetermined
	5/30/2018	Undetermined	Undetermined	Undetermined

BLQ = Below limit of quantification: <50 gene copies/L for *M. avium* and *M. intracellulare*; <100 gene copies/L for *L. pneumophila* serogroup 1

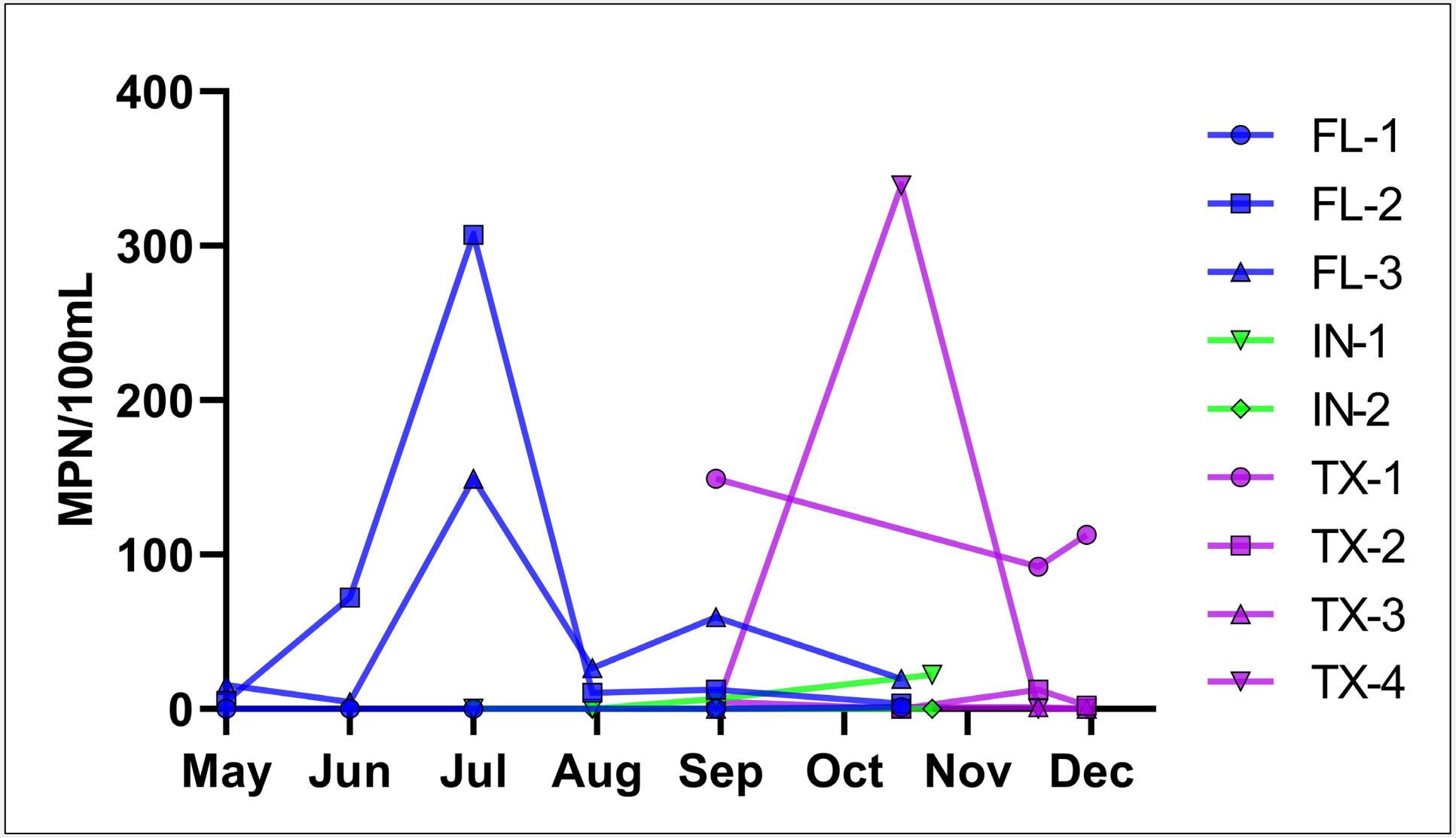
Results: Opportunistic Pathogens in AC

	Legionella pneumophila serogroup 1		*Mycobacterium avium*		*Mycobacterium intracellulare*	
	Detections	Concentrations (gc/L)	Detections	Concentrations (gc/L)	Detections	Concentrations (gc/L)
FL-1	0/6	-	0/6	-	0/6	-
FL-2	1/6	BLQ	0/6	-	0/6	-
FL-3	1/6	BLQ	0/6	-	0/6	-
IN-1	0/4	-	0/4	-	3/4	BLQ to 400
IN-2	0/4	-	0/4	-	3/4	BLQ to 3900
TX-1	0/4	-	0/4	-	0/4	-
TX-2	0/4	-	0/4	-	0/4	-
TX-3	0/4	-	0/4	-	0/4	-
TX-4	0/4	-	0/4	-	0/4	-
NC-1	0/10	-	1/10	200	0/10	-
NC-2	0/10	-	0/10	-	0/10	-
NC-3	1/10	BLQ	0/10	-	0/10	-
NC-4	0/9	-	0/9	-	3/9	BLQ to 1000
NC-1 BF	0/10	-	0/10	-	0/10	-
NC-2 BF	0/6	-	0/6	-	0/6	-
NC-3 BF	0/10	-	0/10	-	0/10	-
NC-4 BF	1/10	BLQ	0/10	-	2/10	BLQ to 100

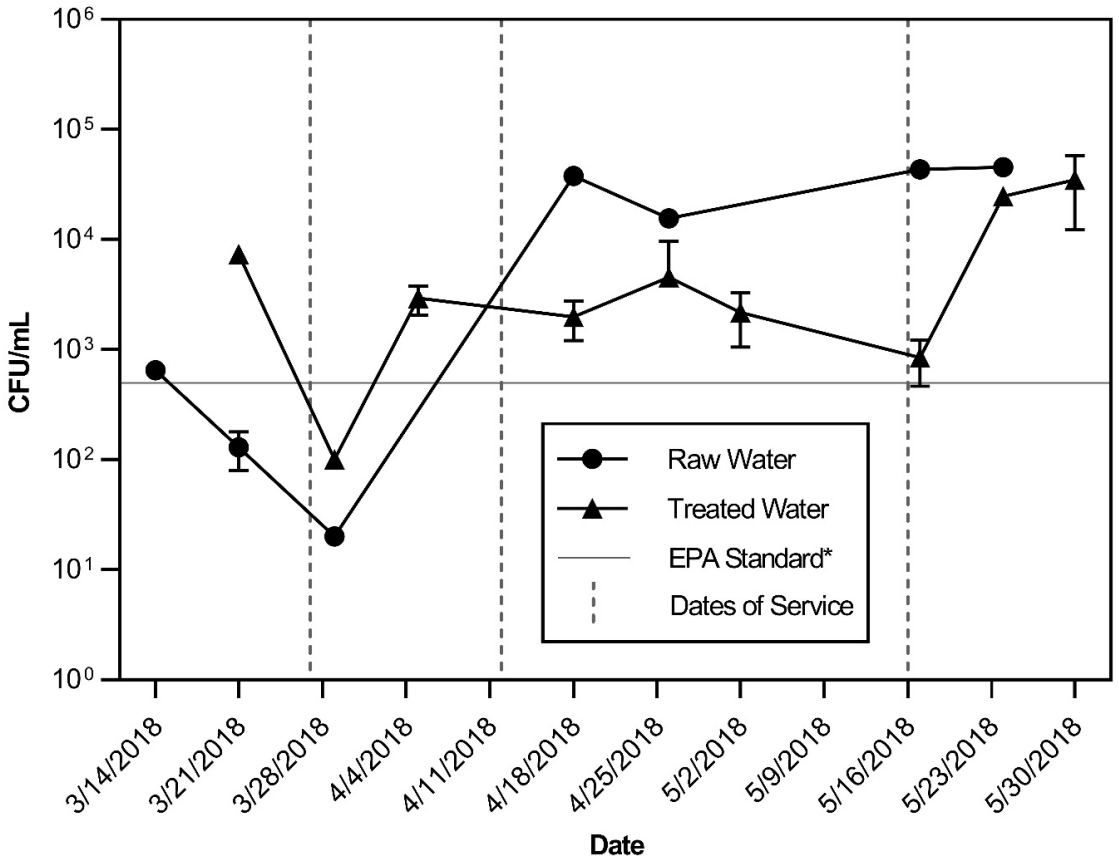
BLQ = Below limit of quantification: <50 gene copies/L for *M. avium* and *M. intracellulare*; <100 gene copies/L for *L. pneumophila* serogroup 1

Results: Opportunistic Pathogens in AC

Legionella spp. by culture



Results: Heterotrophic Bacteria in AWG



*Under EPA's surface water treatment rules, systems may use HPC measurements as an alternative indicator of the presence of a disinfectant residual. Systems in exceedance of the 500 CFU/mL limit in more than 5% of samples each month for two consecutive months are in violation of the regulatory requirements

**Not shown are two samples for which all plates were too numerous to count (TNTC): 3/14/2018 Treated Water was >5,000 CFU/mL; 5/30/2018 Raw Water was >50,000 CFU/mL

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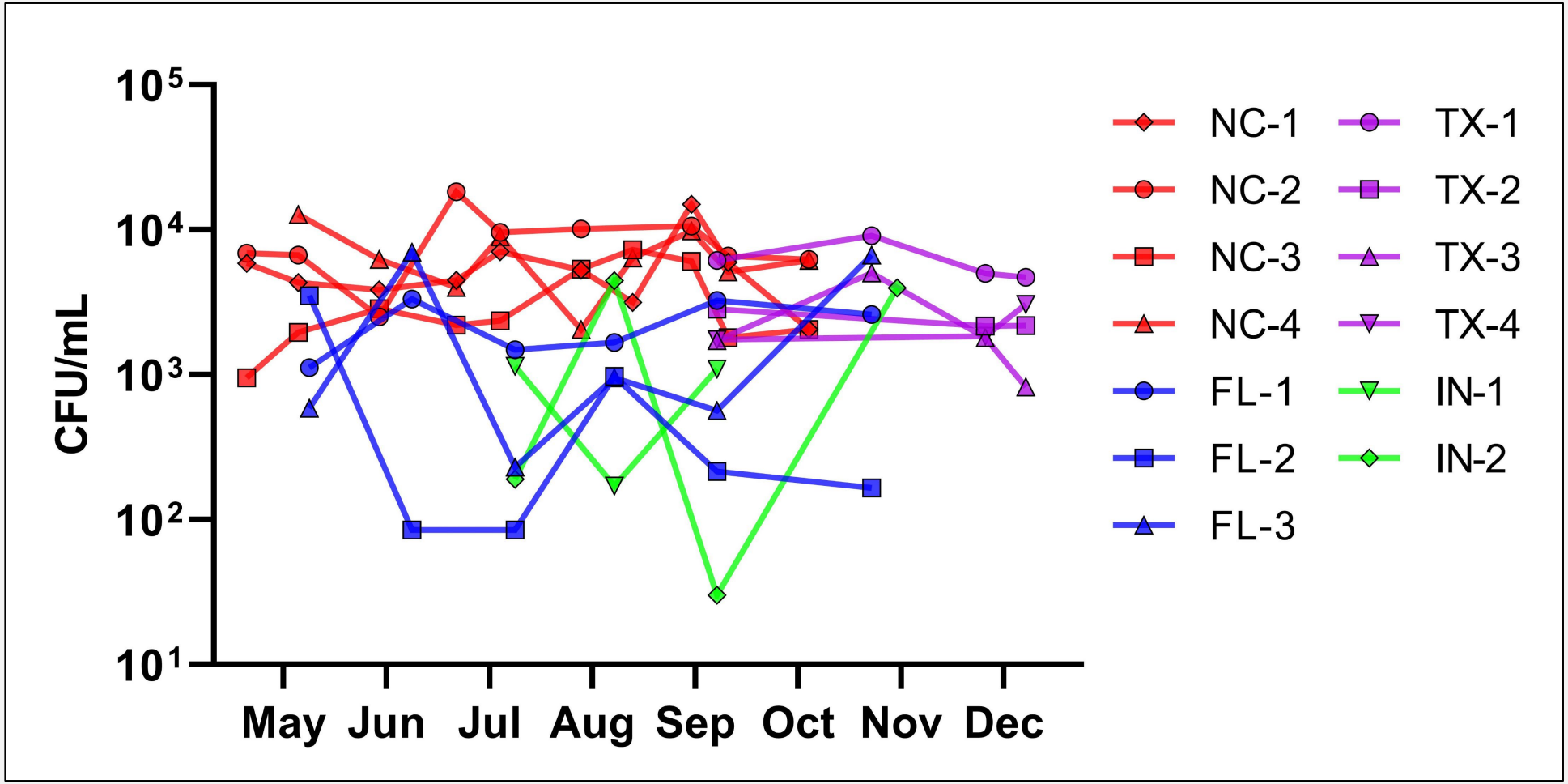
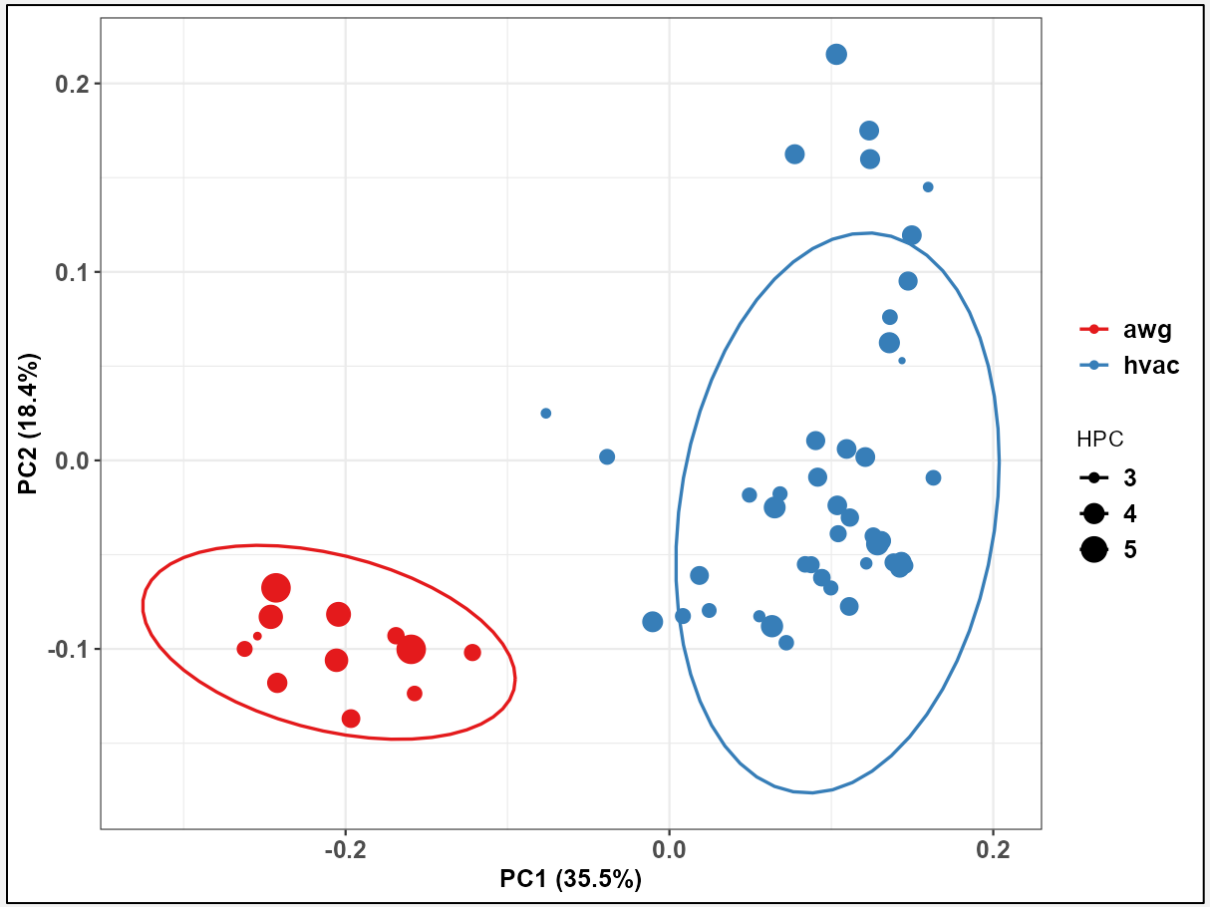
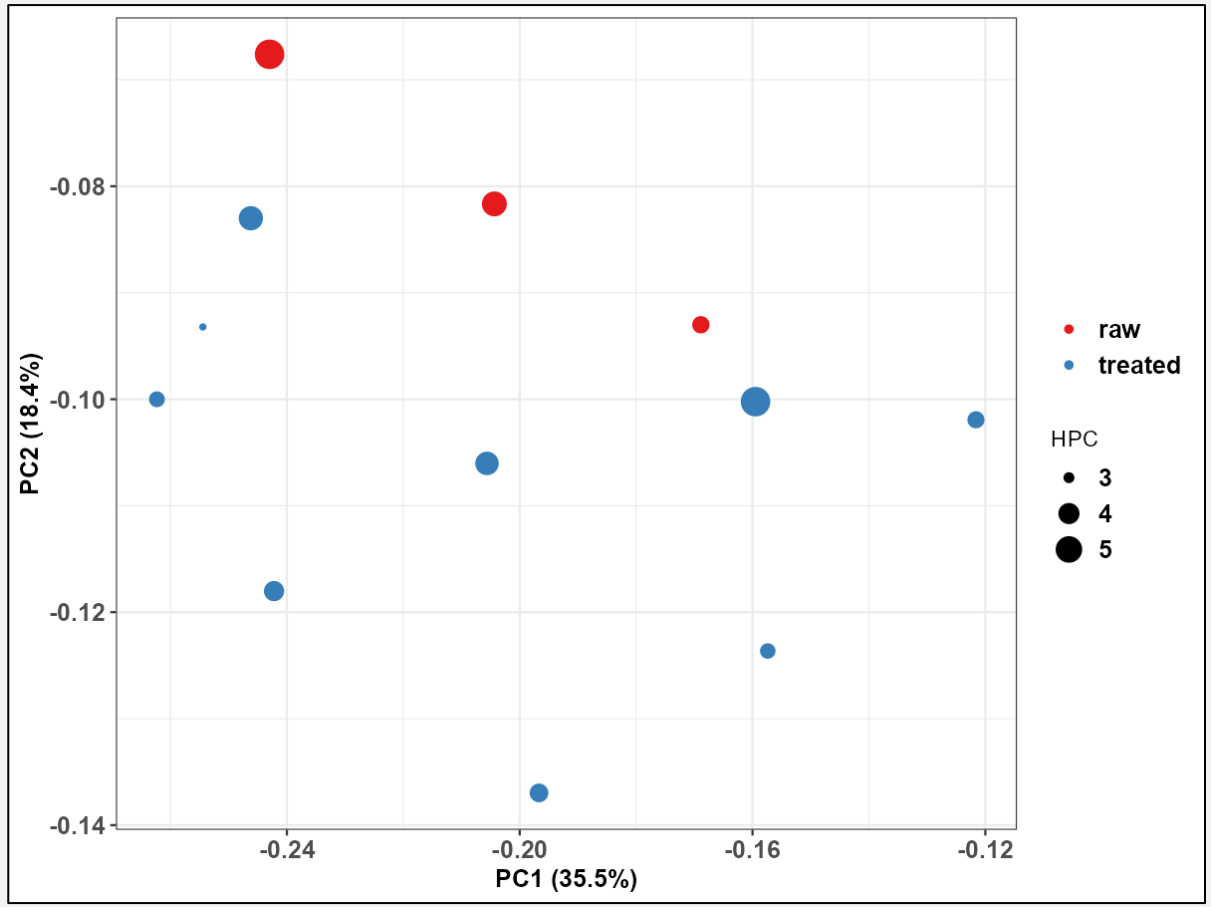
Results: Heterotrophic Bacteria in AC



Results: Community Sequencing

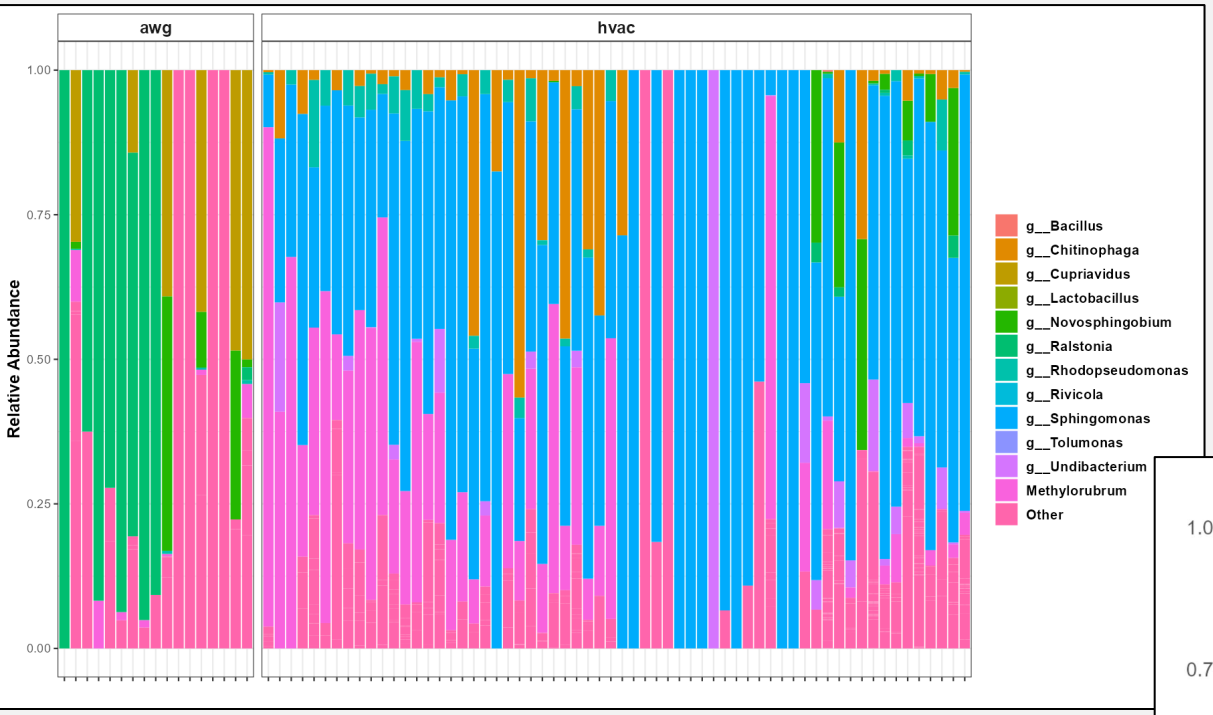


AWG vs. AC Samples



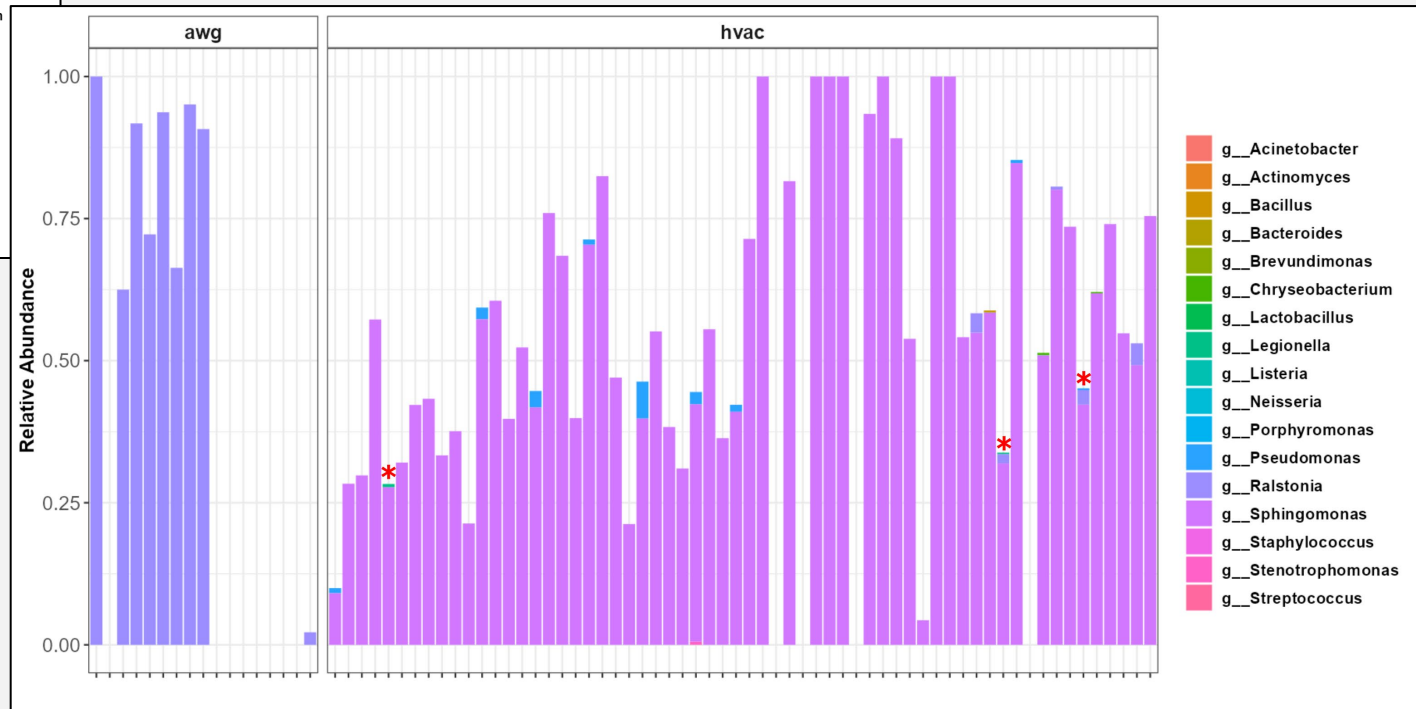
Raw vs. Treated AWG Samples

Results: Community Sequencing



All Bacteria

Potential Pathogens



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Results: Summary and Synthesis

- Data indicate potential for opportunistic pathogens in condensate collections
  - No detections in AWG but several in larger AC study, albeit untreated
  - "High" HPC counts noted across all systems, including UV-treated AWG
  - Diverse microbial communities containing potential pathogen groups
- Microbial instability (growth potential) suggests management need
  - Evidence of inadequate disinfection and/or regrowth in distribution lines
  - Disinfection with residual: chlorination or ozone (for short residence times)
  - 0.2 mg/L free chlorine residual common target for conventional systems
  - Maintenance of storage and distribution systems to minimize growth
- Bottom line: Same management requirements for all water distribution systems, regardless of source
  - Check with state/local permitting agency regarding compliance needs

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Thank you – Questions?

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