The Relationship Between Drinking Water Quality in a Single Family Home and the Service Line

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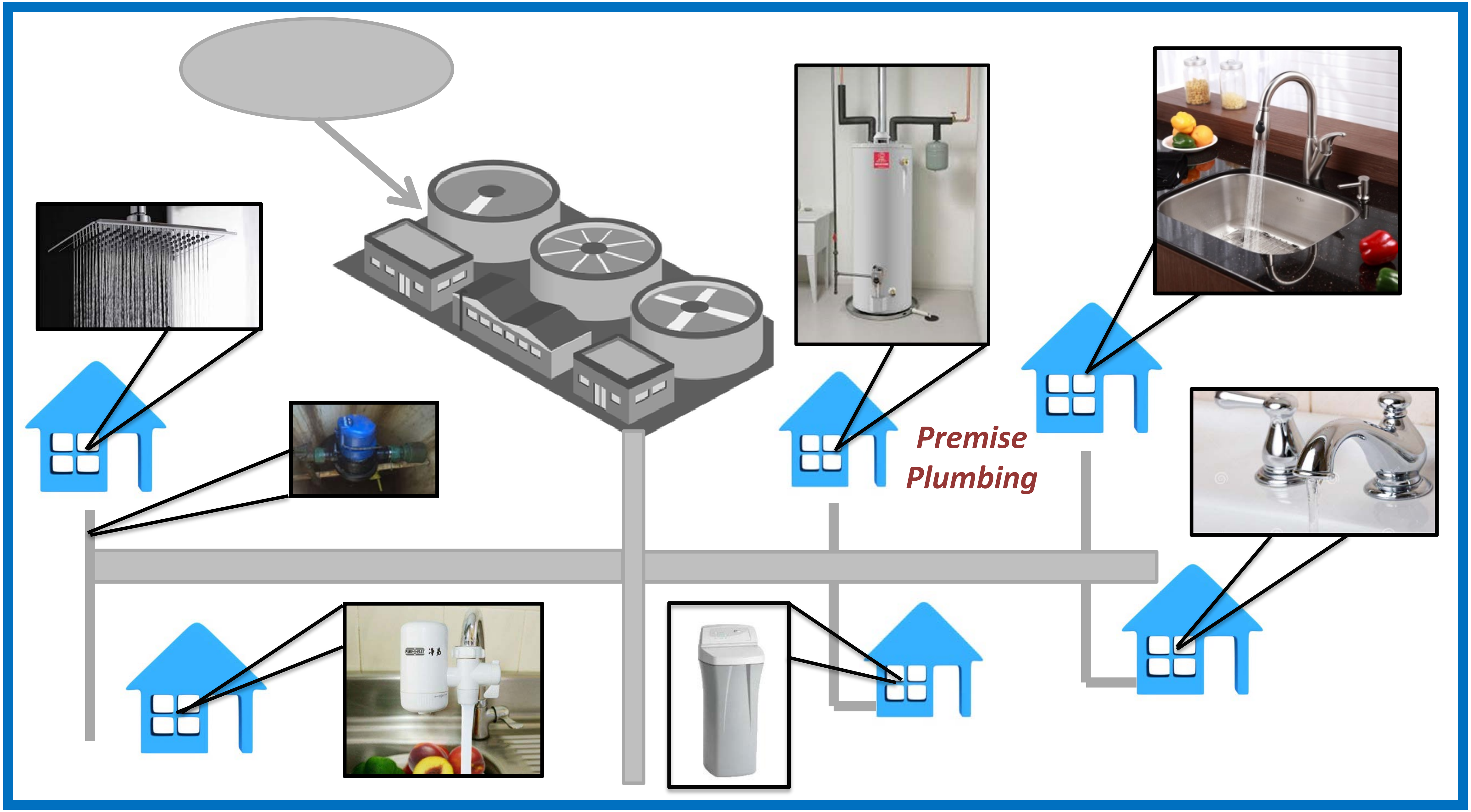
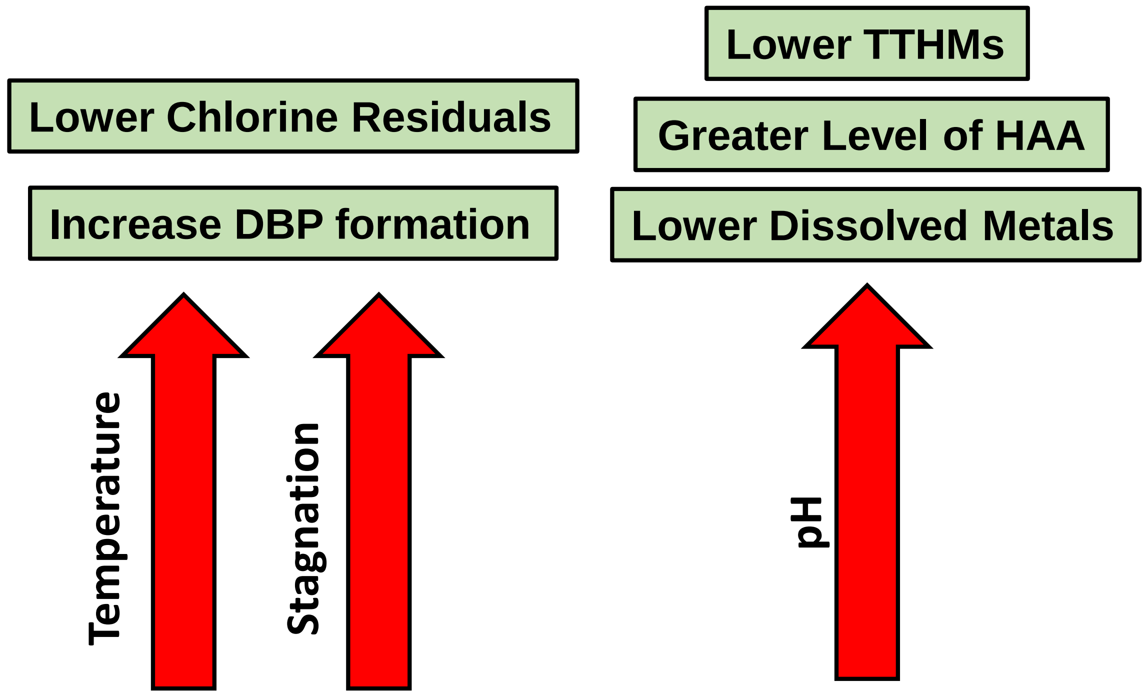

Premise
Plumbing

Changes to contaminant levels can been attributed to plumbing materials, temperature, pH, and water stagnation.

The time of day and season can influence water quality characteristics.



The Link between Fixture Water Use and Drinking Water Quality at a Net Zero Energy Residential Building

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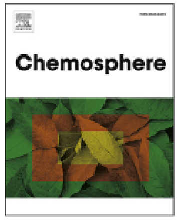

Case study: Fixture water use and drinking water quality in a new residential green building

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Research Goal	Investigate temporal & spatial variations of tap water chemical quality at a net-zero energy building.
	Examine water chemical quality fluctuations at the point of entry the building.
Objectives	Elucidate spatial and temporal variations of water quality inside the building.
	Explore the reasons caused spatial and temporal variations of tap water quality.

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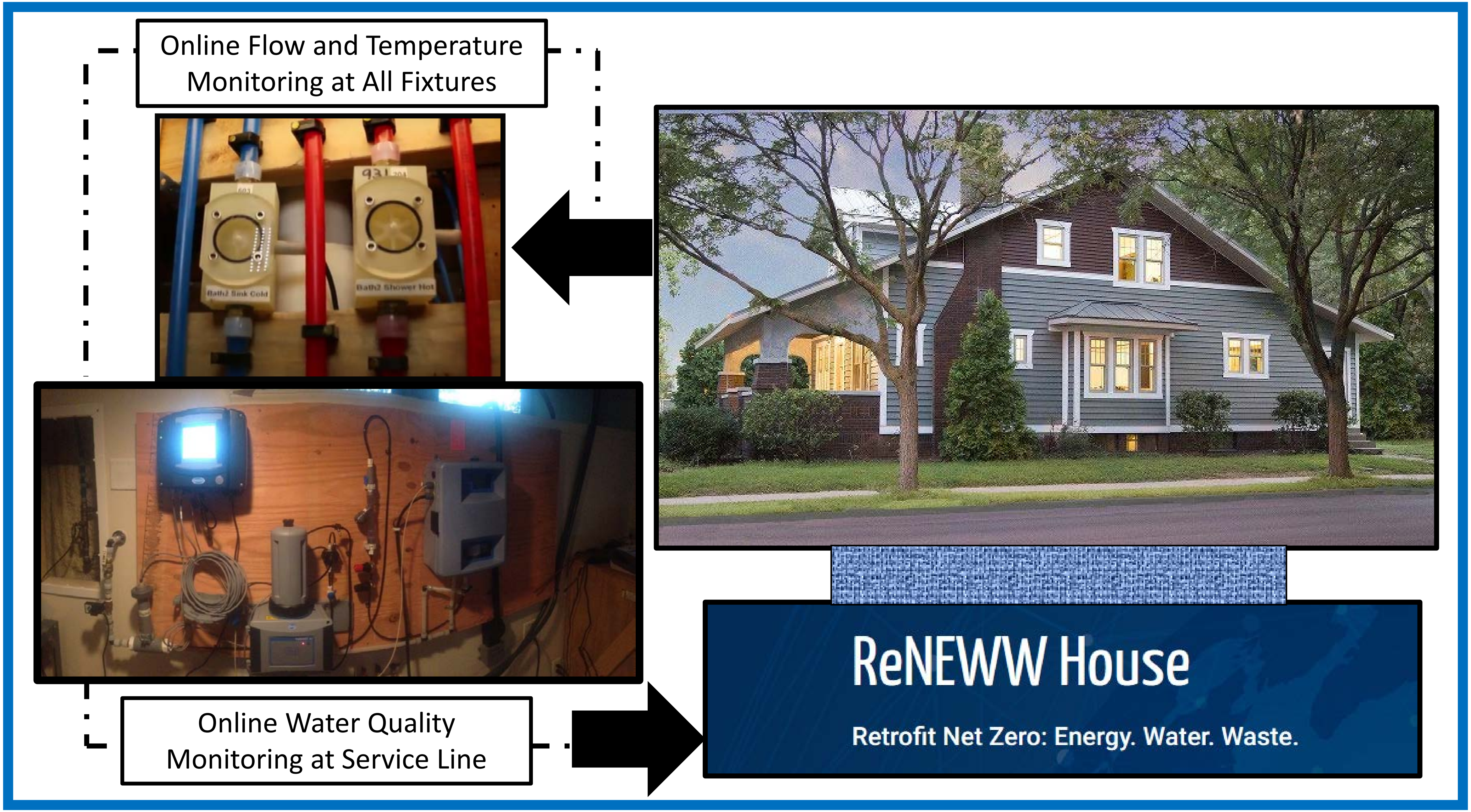
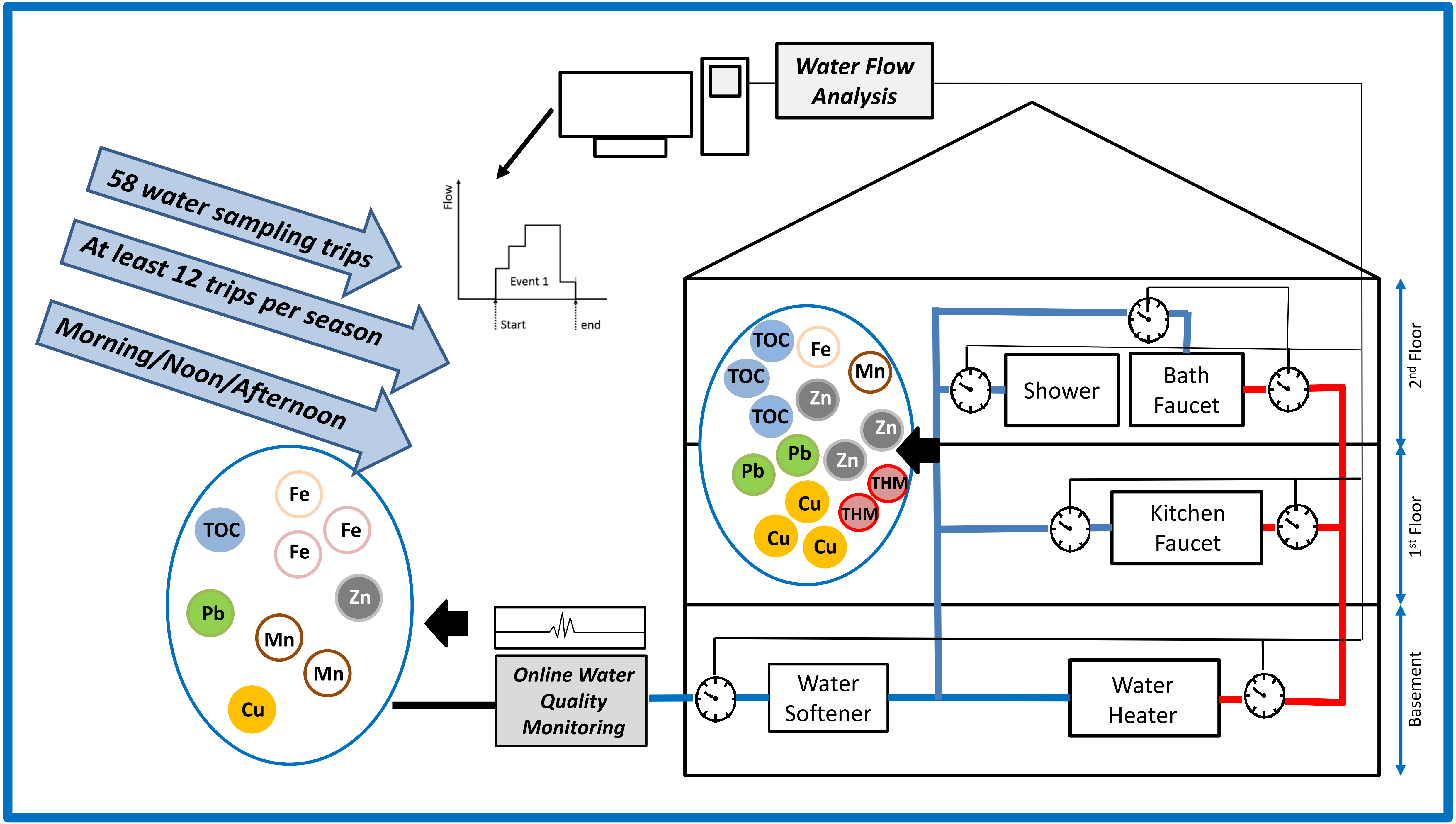

Online Flow and Temperature Monitoring at All Fixtures
Online Water Quality Monitoring at Service Line
ReNEWW House
Retrofit Net Zero: Energy. Water. Waste.



Water Flow Analysis
Flow
Event 1
Start
end
58 water sampling trips
At least 12 trips per season
Morning/Noon/Afternoon
TOC
Fe
Mn
Zn
Pb
Cu
THM
Shower
Bath Faucet
Kitchen Faucet
Water Softener
Water Heater
Online Water Quality Monitoring
2nd Floor
1st Floor
Basement

Low Water Use and In-Building Stagnation Varied by Season

Season (Occupancy/Day) and Water Use Characteristics			Fixture Locations						
			Service Line	*1st Flr Cold*	*2nd Flr Cold*	*2nd Flr Shower*	*Water Heater*	*1st Flr Hot*	*2nd Flr Hot*
Fall (2.8)[1]	*Total Volume, m³*		25.5	0.9	0.4	8.1	8.7	1.0	3.5
	Stagnation, hr	$\bar{x}$	0.3	1.0	2.2	2.3	0.5	1.2	1.1
		90th tile	0.0	2.2	7.3	3.6	0.9	2.0	2.5
		Max	37.5	153.0	102.7	120.0	152.0	153.0	150.2
Winter (2.2)[1]	*Total Volume, m³*		23.6	0.8	0.4	7.3	8.3	1.0	4.8
	Stagnation, hr	$\bar{x}$	0.3	1.1	3.2	3.4	0.4	1.0	1.1
		90th tile	0.6	2.2	9.7	9.3	0.8	2.0	2.2
		Max	16.0	99.4	69.9	72.3	50.7	72.9	72.6
Spring (1.5)[1]	*Total Volume, m³*		19.7	0.5	0.2	4.7	5.9	0.8	2.5
	Stagnation, hr	$\bar{x}$	0.5	2.2	5.3	4.5	0.7	1.6	1.7
		90th tile	1.0	4.1	11.6	13.8	1.1	2.8	3.0
		Max	25.8	114.1	123.1	60.7	68.9	116.2	67.0
Summer (2.7)[1]	*Total Volume, m³*		23.8	0.9	0.2	3.7	4.3	0.7	1.0
	Stagnation, hr	$\bar{x}$	0.1	1.3	3.9	5.7	0.7	1.6	1.7
		90th tile	0.1	2.2	7.6	15.6	1.2	2.6	3.0
		Max	47.0	118.6	145.1	79.0	95.4	142.5	65.8

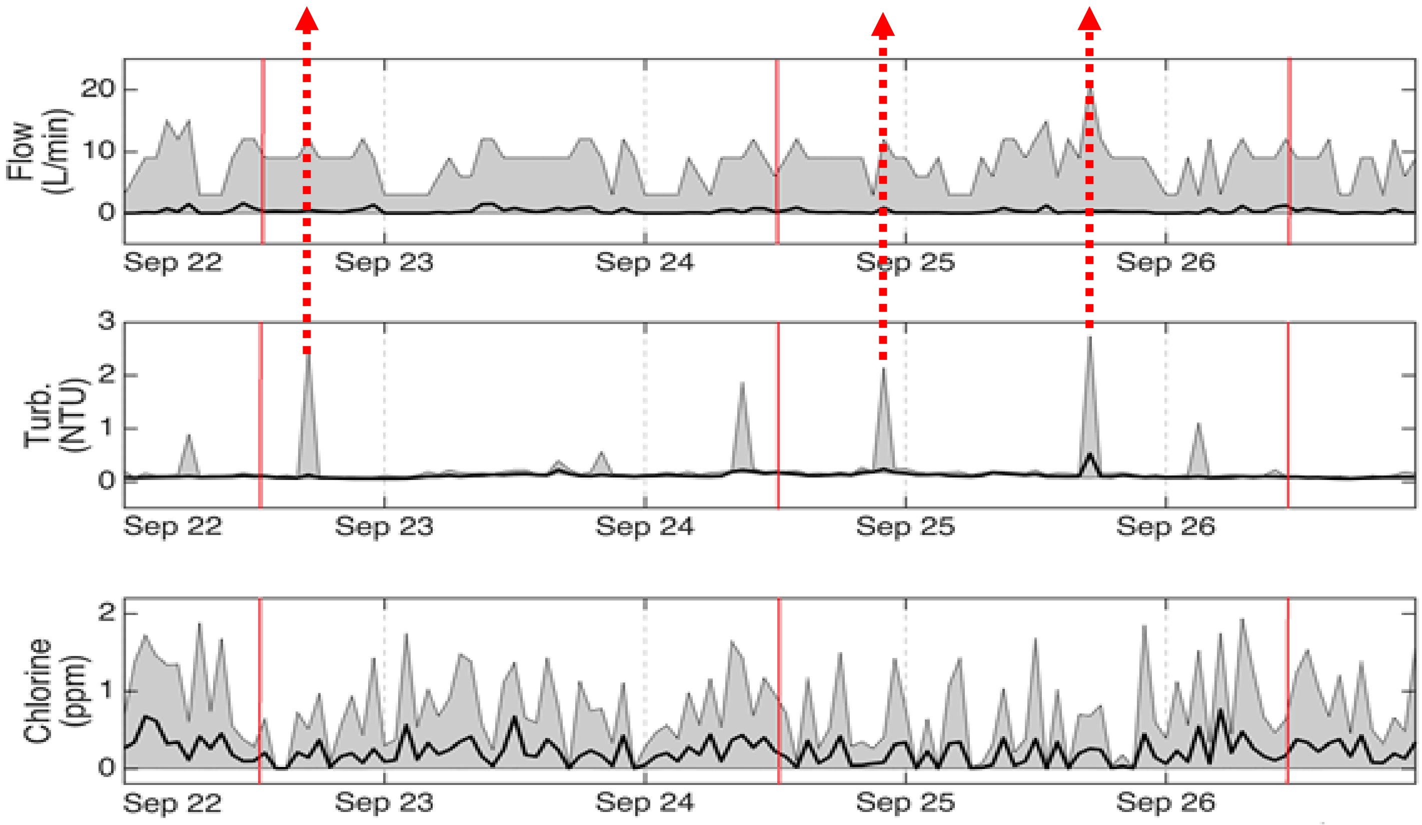
[1] Average outdoor temperature: 5.4 °C (Fall), -0.7 °C (Winter), 15.6 °C (Spring), 22.6 °C (Summer), calculated using data reported at *Weather Undergrounded.* Average daily occupancy is reported as persons/day. x = mean.

Water Quality Significantly Varied at the Service Line

Parameter		Public Water System	Fall	Winter	Spring	Summer
General	Temp, °C	nr	21.6	14.6	21.1	22.9
	pH	7.6	7.7	7.7	7.7	7.5
	Total Cl_2, mg/L	1.2	0.4	0.9	0.6	0.4
	Free Cl_2, mg/L	nr	0.3	-	0.4	0.4
Organics	TOC, mg/L	nr	0.5	0.5	0.6	0.5
	DOC, mg/L	nr	0.5	0.5	0.5	0.5
	TTHM, µg/L	19.2[3]	<1.4	<1.4	2.5	<1.4
Heavy Metals	Pb, µg/L	nd[6]	<1.1	<1.1	<1.1	<1.1
	Zn, µg/L	nr	14.3	14.1	26.6	10.4
	Cu, µg/L	565[3]	81.2	75.5	72.6	32.2
	Fe, µg/L	20[1]	19.1	16.7	6.2	6.7
	Mn, µg/L	20[1]	3.1	2.9	1.8	2.0
Nitrogen	NH_3-N, mg/L	nr	0.4	<0.01	<0.01	0.1
	NO_3-N, mg/L	0.2	0.5	0.8	0.6	0.1

Online Service Line Monitoring Confirmed Drinking Water Quality Fluctuations

Turbidity peaks match peak flow rates, and may indicate hydraulic impacted biofilm and inorganic scale suspension.



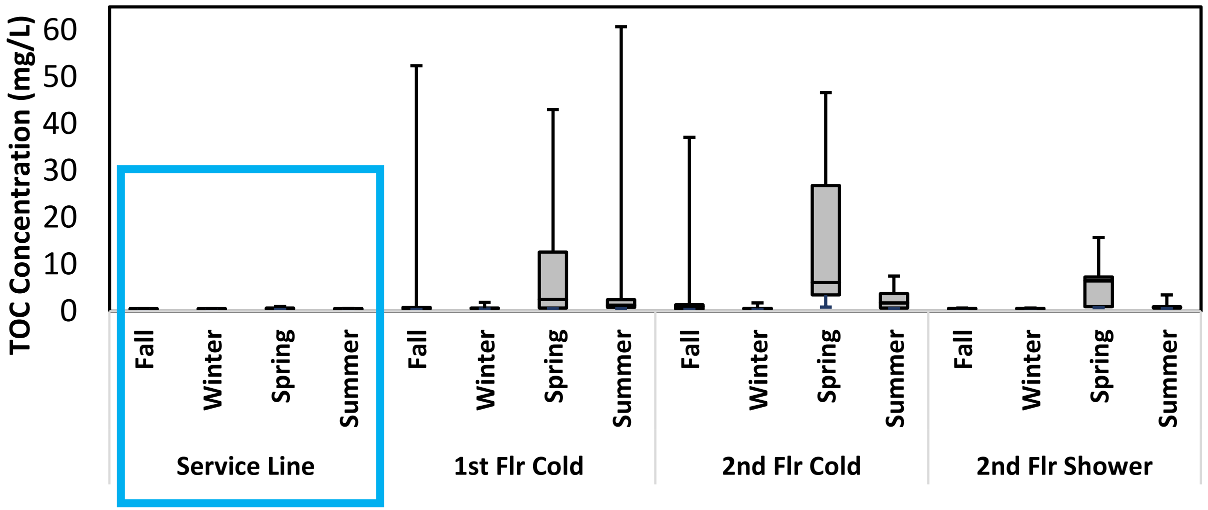
Online water quality monitoring

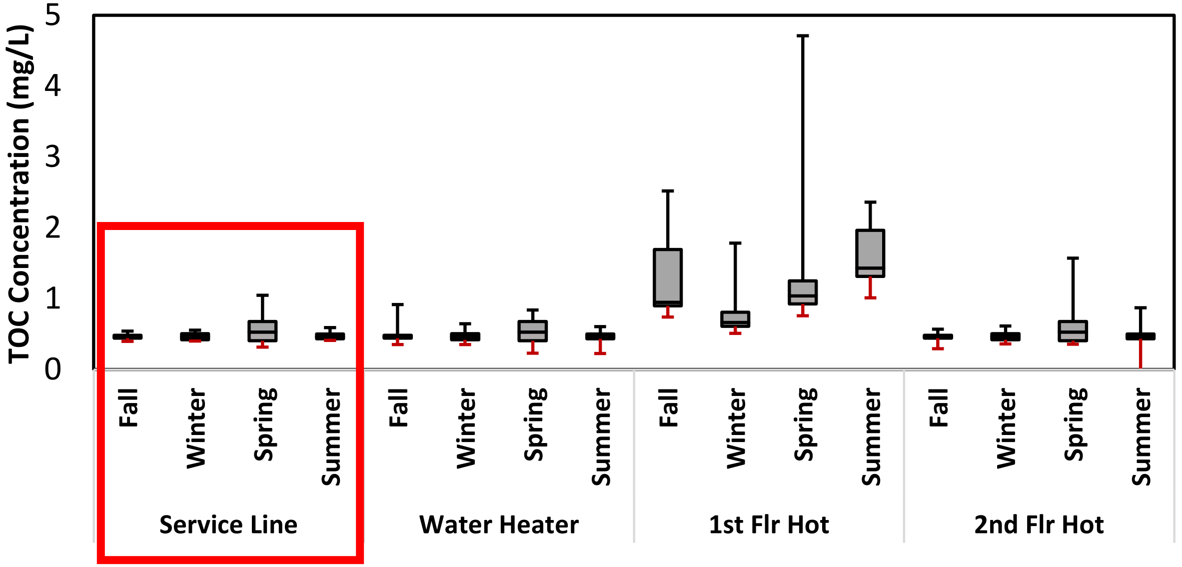
Water pH and water temperature increased in the building

- **Water pH at the service line (7.2-7.8)** *Increased* → **through the building (7.2-9.4).**
- **The greatest water pH values were found at the 1st floor cold (7.5-9.4) and 2nd floor hot (7.7-9.0) water fixtures.**
- **About 11% of all faucet pH values exceeded the SMCL of 8.5.**
- **Water temperature at the service line (19.6 °C)** *Increased* → **through the building (23 °C).**

TOC levels were often greatest in the cold water plumbing.

A positive correlation was found between organic carbon concentration with water pH.





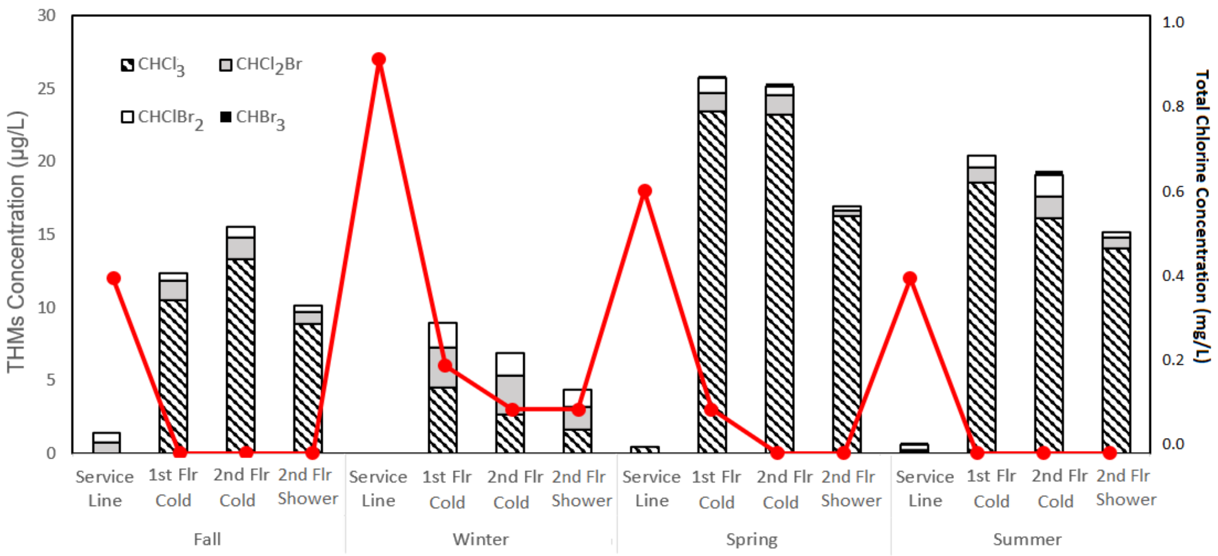
Bench Scale Study: pH and temperature influenced organic release

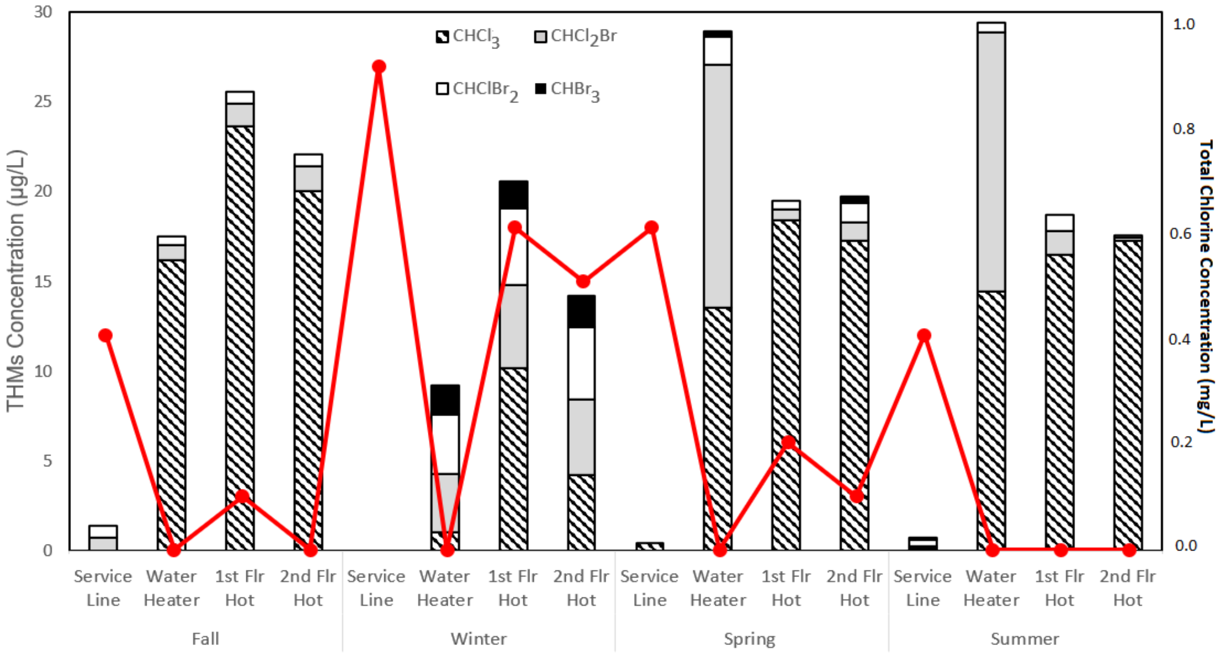
Water pH and Exposure Time		Total Organic Carbon (TOC) Concentration (mg/L)			
		PEX-a Pipe		PEX-b Pipe	
		23°C	50°C	23°C	50°C
pH 7	Day 3	13.09	41.29	16.66	58.92
	Day 15	3.33	5.71	0.89	12.88
	Day 30	5.07	3.44	1.08	10.77
	Sum	*21.49*	*50.44*	*18.63*	*82.57*
pH 10	Day 3	-	77.69	-	39.95
	Day 15	-	5.64	-	7.26
	Day 30	-	1.55	-	5.25
	Sum	-	*84.88*	-	*52.46*

Disinfectant residual levels decreased through the building while TTHM concentrations increased.

For more than 85% of the sampling trips, disinfectant residual was not detected at the water heater, the 2nd detected at the water heater, the 2nd floor cold, and 2nd floor shower fixture.

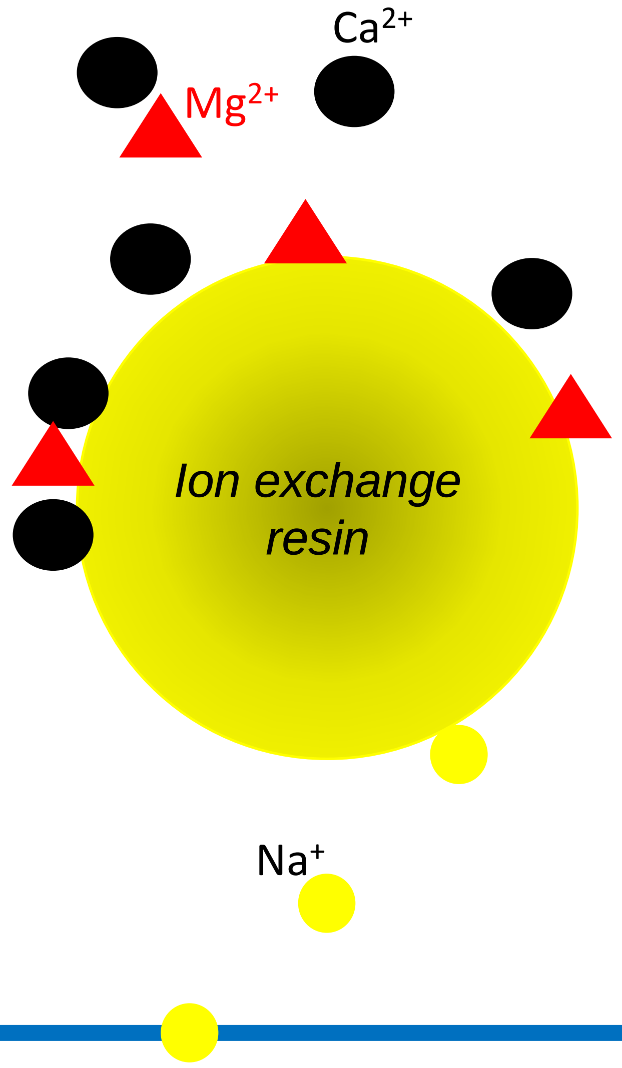
A significant negative correlation between Temp & disinfectant residual at all fixtures except the water heater and 2nd Flr shower



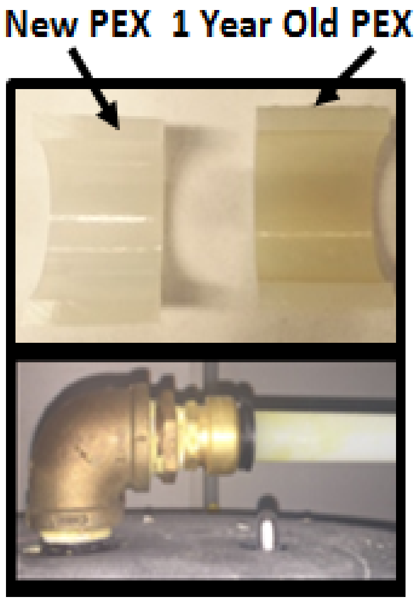


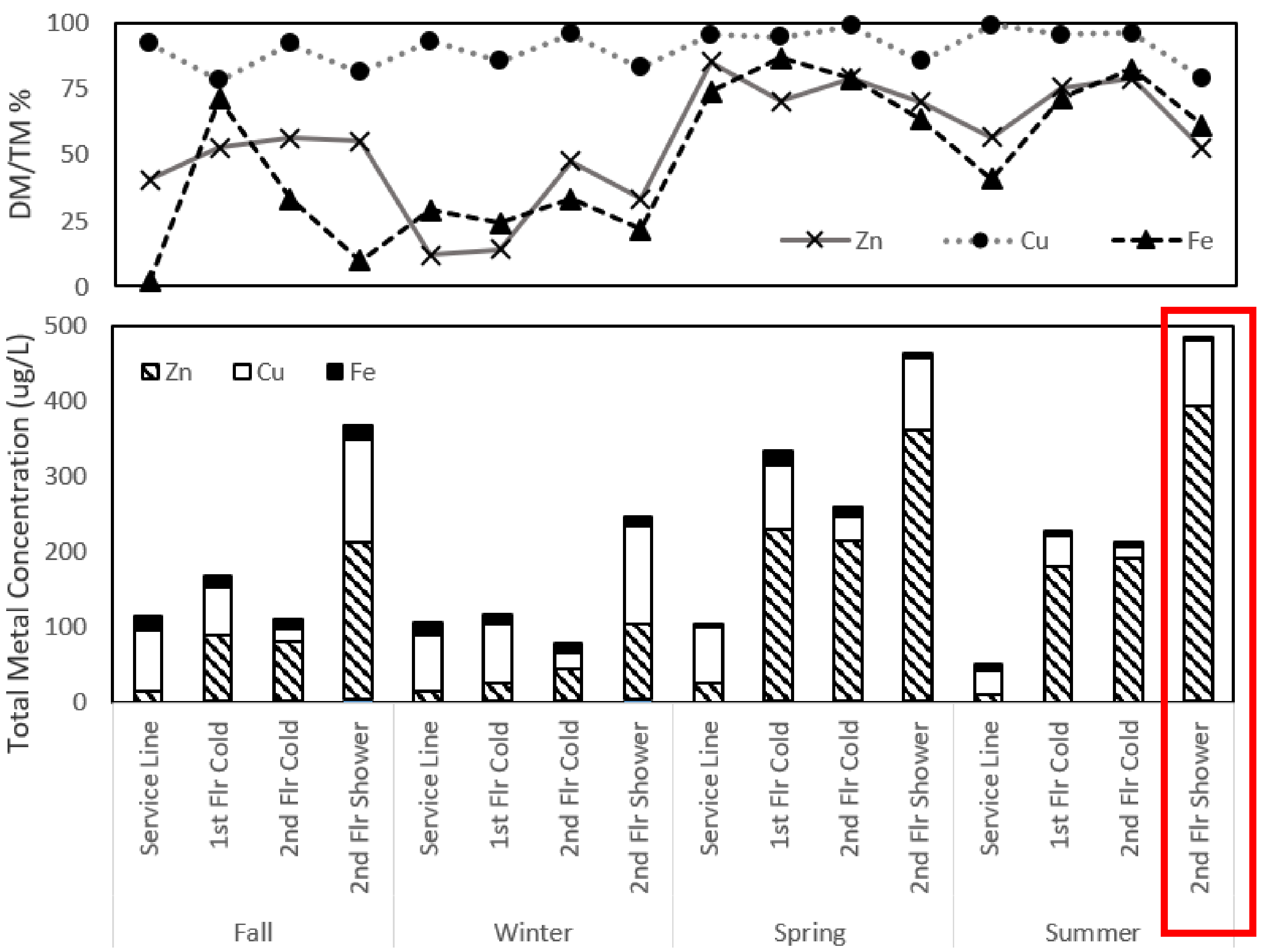
The water softener treated all water from the service line

Hardness	385 mg/L as $CaCO_3$	19 mg/L as $CaCO_3$
Ca^{2+}	99 mg/L	2 mg/L
Mg^{2+}	34 mg/L	4 mg/L
Na^+	23 mg/L	178 mg/L
	At Service Line	*In Building*



Zn, Pb & Cu leached from the building plumbing while Fe & Mn deposited onto the plumbing.





Potential Seasonal Nitrification

- Study results suggest seasonal nitrification occurred in the hot water plumbing.

- NO_2-N was not detected at the service line or cold water samples, but was found during short Spring and Summer periods (0.02-0.05 mg/L) in hot water plumbing.

- Significantly lower NO_3-N levels were found in afternoon water samples compared to the morning or mid-day.

$$NH_3 \downarrow NO_2 \downarrow NO_3$$

The Need for Technology & Considerations for Future Building Water Quality Studies

- The sensor technology is needed to better capture water quality variability at the service line and within buildings.

Future studies should consider:

- The impact of new and aged (or established) plumbing on water quality.
- The role hydraulic factors contribute to biofilm or scale suspension and thereby delivery to plumbing fixtures.
- Contaminant deposition and release within plumbing.