New Developments In Premise Plumbing: Integrated Hydraulic and Water Quality Modeling

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Key Takeaways

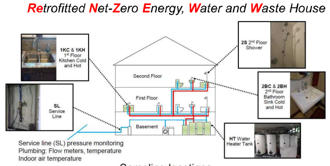
- Predicting water safety at the faucet is a goal of advancing public health
- Previous studies have demonstrated that the water quality at the faucets diverge from the water in the distribution system and are affected by temporal conditions.
- Temporal and spatial conditions have also been shown to impact water quality
- Knowledge of the deterioration in water quality from the distribution system to the building fixtures raises the need to predict the water quality at the faucets under varying parameters.
- This study developed hydraulic and water quality models with outputs of time-series based water quality predictions at the fixtures of a residential home.
- Results of this study demonstrated an increase in microbial and chemical contaminant concentrations with higher service line length, lower pressure, and lower demand flow rate.

Goals and Objectives

- The objective of the project was to develop Integrative Hydraulic-Water Quality Predictive Tools that closely mimic residential buildings.
- The calibrated premise plumbing hydraulic-water quality models were developed for the extensively monitored ReNEWW house (http://www.renewwhouse.com/) to predict drinking water disinfectant residual, TTHM, heavy metals, and microbial quality at each fixture with plumbing use, design, and operation characteristics.

Fieldwork | Water quality & Hydraulics

Retrofitted Net-Zero Energy, Water and Waste House



Sampling locations
50x, hot & cold water, 7am, 12pm, 3pm

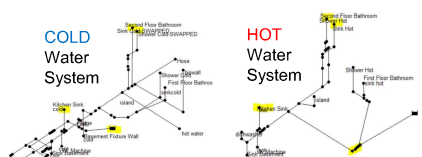
- Area: 266 m^2, 4 bedrooms, 1.5 baths
- Study Period: Oct. 2017-Oct. 2018
- 30, 000+ water quality measurements
- 2.64 billion online hydraulic plumbing measurements
  - Pressure @ SL/ water demand at each fixture

Methods

1. *EPANET 2.2/ EPANET-MSX Files*

COLD Water System

HOT Water System



EPANET 2.2:
- Water demand/flow use
- Pipe network design

EPANET MSX
- Water quality parameters
- Chemical/microbial contaminant concentrations

Free Chlorine: $\frac{dC_{FCL}}{dt} = -KC_{FCL}$

NO_3: $\frac{dC_{NO_3}}{dt} = -k_{NO_3}\theta_{NO_3}^{T-2} C_{NO_3}$

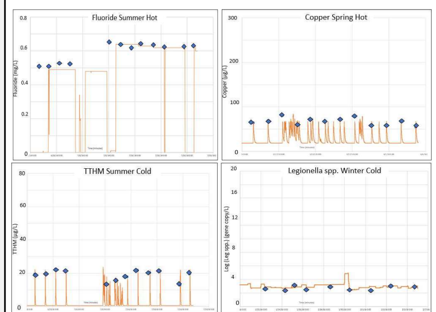
Legionella spp. : $N_{tLEG} = N_{0LEG}e^{-a}$

HPC: $\frac{dC_{HPC}}{dt} = Y_h\left(q_m\left[\frac{BOM}{k_s+BOM}\right]\right)C_{HPC} - k_d[HOCL]$

TTHM: $\frac{\partial C_{TTHM}}{\partial t} = k(C_{TTHMMAX} - C_{TTHM})$

Cu, Fe, Pb: $\frac{dC_{HeavyMetal(HM)}}{dt} = \frac{AM}{V}\frac{E-C_{HM}}{E}$

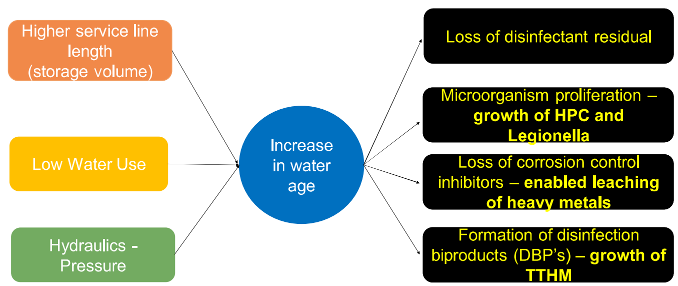
2. *Calibrations*



- 4 seasons, 2 systems (hot/cold)- 8 models - correlate to 2018 sampling periods
- 1-minute time intervals
- Selection criteria: Root Mean Square Error (RMSE), Normalized RMSE (NRMSE), NASH-Sutcliffe (NSE)(N.D. Bennett et al., 2013), Percent bias (PBIAS) (Gupta et al. 1999)
- Conserved specie fluoride modeled to validate calibrations

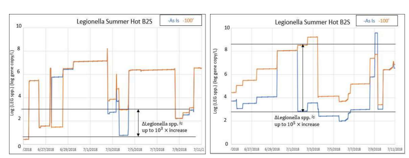
3. *512 Selected Scenarios*

4 Seasons (Summer, Fall, Winter, Spring) • **2** Systems (Cold, Hot) • **4** Conservation Scenarios (25%, 50%, 100%(As Is), 200%) • **4** Service Line Length (1' (As is), 25', 50', 100') • **2** Pressure boundary conditions (35/40PSIG (As is cold/hot), 80PSIG)



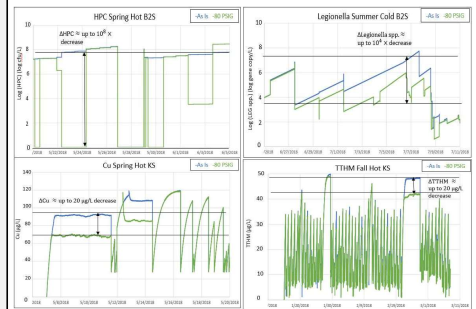
Results

I. *Increasing service line length to 100'*



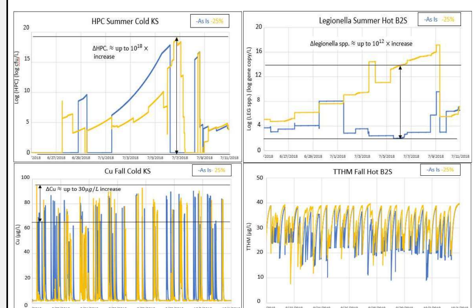
- Legionella spp. gene copy number / L tends to increase in the Summer hot and cold season up to 10^5-fold

II. *Increasing service line pressure to 80 PSIG*



- HPC concentration decreased up to 10^8-fold
- Legionella spp. concentration decreased up to 10^4 -fold
- Copper concentration decreased up to 20 μg/L.
- TTHM concentration decreased up to 20 μg/L.

III. *Reduction of flow rate to 25% of observed conditions*



- Legionella spp. levels increased up to 10^{12}-fold Summer hot season.
- HPC levels increased up to 10^{18}-fold in Summer cold season
- Copper concentration increased up to 30 μg/L in Fall cold season.
- Small but consistent increase in TTHM concentration in Fall hot season.

Limitations

- **Grab Sampling-**Limited ability to predict what happens between the sampling events. Online sensors allow for continuous data collection
- **Water Quality Fluctuations and Sensors-** Results were driven by variable water quality delivered, plumbing demand, and method detection limit
- **Fundamental limitation of governing Equations-** Dispersion issues
- **Number of Scenarios-**Manual running of Scenarios. Possibility of thousands of generated scenarios is in progress

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