Microbial Community Structure Changes as a Building Transitions Between In-Situ Rainwater Treatment and Municipal Drinking Water

Christian J. Ley,[1] Maryam Salehi,[2] and Andrew J. Whelton[1,2]

[1] Environmental and Ecological Engineering, Purdue University, West Lafayette, IN 47907

[1,2] Lyles School of Civil Engineering, Purdue University, West Lafayette, IN 47907

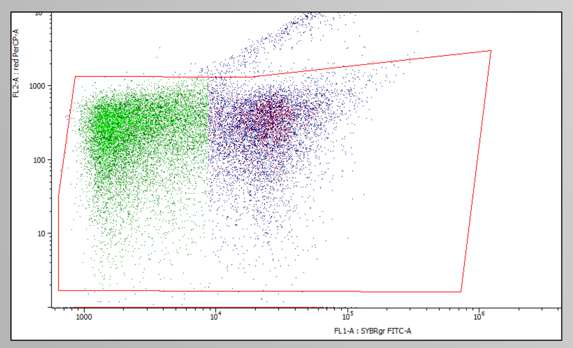
Overview

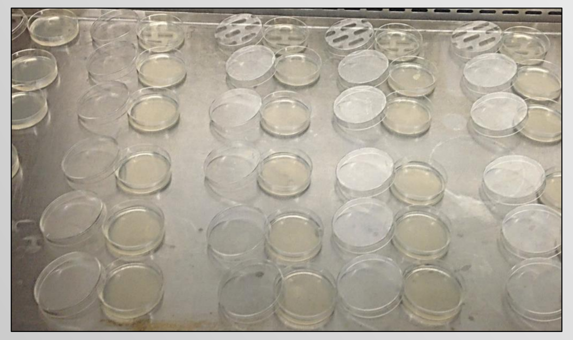
Water conservation trends have given rise to the use of rainwater for in-building drinking water applications. Studies indicate that onsite rainwater storage, in the absence of disinfectant residual, may promote the growth of opportunistic pathogens and other potentially harmful bacteria. The study objective is to characterize the microbial transition at a renovated single-family residential building before and after switching the potable water system from rainwater to municipal water. Currently, the PEX plumbed building obtains drinking water from a community groundwater system, and will transition to rainwater in October 2018. Hydraulic data including fixture use frequency, volume used per event, and stagnation time are being used to develop an integrated hydraulic and water quality model. Microbial quality of the water was evaluated by heterotrophic plate count (HPC) methods and flow cytometry to quantify culturable bacteria levels and total cell counts, respectively.

Study Objectives

1. Characterize the microbial transition at a residential building after switching the potable water from rainwater to municipal water.
2. Evaluate the seasonal effects on microbial water quality
3. Compare the use of flow cytometry to traditional culture-based methods to rapidly assess microbial quality of drinking water

Flow Cytometry vs. Plating





FLOW CYTOMETRY
- Rapid analysis
- Quantifies entire population
- Provides description of nucleic acid content
- Measurement range: 1.0 x 10^3 – 2.0 x 10^5 cells/ml (EAWAG, 2012)

HPC PLATING
- Time consuming, requires 48 h minimum
- Quantifies culturable bacteria for specific growth conditions
- Only detects <1% of bacteria (Van Nevel, 2017)

Experimental Methods

Onsite Analysis
Total Chlorine
Dissolved O_2
Temperature and pH

Chemical Analysis
Metals and IC
TOC and DOC
Alkalinity and TTHM

Microbial Analysis
Flow Cytometry
Heterotrophic Plate Counts
qPCR

Hydraulic Monitoring
Fixture use frequency
Volume per event
Stagnation time

Flow Cytometry Analysis → 1: 100 Dilution SYBR green stain to sample → Incubate 13 minutes at 37° C → Cytoflex Flow Cytometer 10 uL/s, 30s,

Heterotrophic Plate Count → Collect, filter, and plate samples onto mHPC agar → Incubate 48 hours 35° C → Count colony forming units

ReNEWW HOUSE
West Lafayette, Indiana
www.ReNEWWHouse.com

Preliminary Results

Table 1: Potable water quality parameters in ReNEWW house

Chemical Parameter	Service Line	Kitchen Sink
Temperature (° C) (n =6)	11.5 – 19.0	19.5- 21.4
pH (n = 21)	7.65 – 7.81	7.71 – 8.66
Total Chlorine (mg/L) (n= 21)	ND – 1.6	ND – 0.7
Total Organic Carbon (mg/L) (n = 19)	0.39 – 1.05	0.50 - 41.76

Table 2: Microbial water quality in ReNEWW house

	Post-Rainwater Transition (n=3)	Municipal Water Use (n=12)
Heterotrophic Plate Count (CFU/ 100 mL)	4.1 x 10^3 – 8.2 x 10^5	1.74 x 10^2 – 9.33 x 10^5
Assimilable Organic Carbon (ug/L)	22.7 – 144.3	14.8 – 50.9
Total Cell Counts (cells/mL)	2.27 x 10^8 – 1.44 x 10^9	1.48 x 10^5 – 5.15 x 10^5

Table 3: Assimilable organic carbon and HPC by fixture

Fixture (n=21)	AOC Range (ug/L)	Mean AOC (ug/L)	Mean HPC (CFU/100 mL)
Service Line	4.9 - 79.3	25.4 ± 18.5	1.39 x 10^3
Water Heater	8.9 - 99.6	72.2 ± 45.9	2.57 x 10^4
Kitchen sink hot	8.0 - 85.1	57.7 ± 35.0	1.74 x 10^2
Kitchen cold	2.5 – 69.1	28.5 ± 21.1	1.18 x 10^3
Bath. sink hot	9.6 – 89.7	57.4 ± 34.7	9.17 x 10^3
Bath. sink cold	1.4 – 61.1	21.3 ± 18.1	6.16 x 10^3
Shower	2.0 – 30.0	16.6 ± 7.7	9.33 x 10^5

Table 4: FCM analysis of cellular nucleic acid content (n =17)

Fixture	% Low Nucleic Acid Cells	% High Nucleic Acid Cells
Service Line	93.9	6.13
Water Heater	92.7	7.29
Kitchen sink hot	96.5	3.47
Kitchen sink cold	97.9	2.14
Bathroom sink hot	92.8	7.25
Bathroom sink cold	92.9	7.03
Shower	93.9	6.07

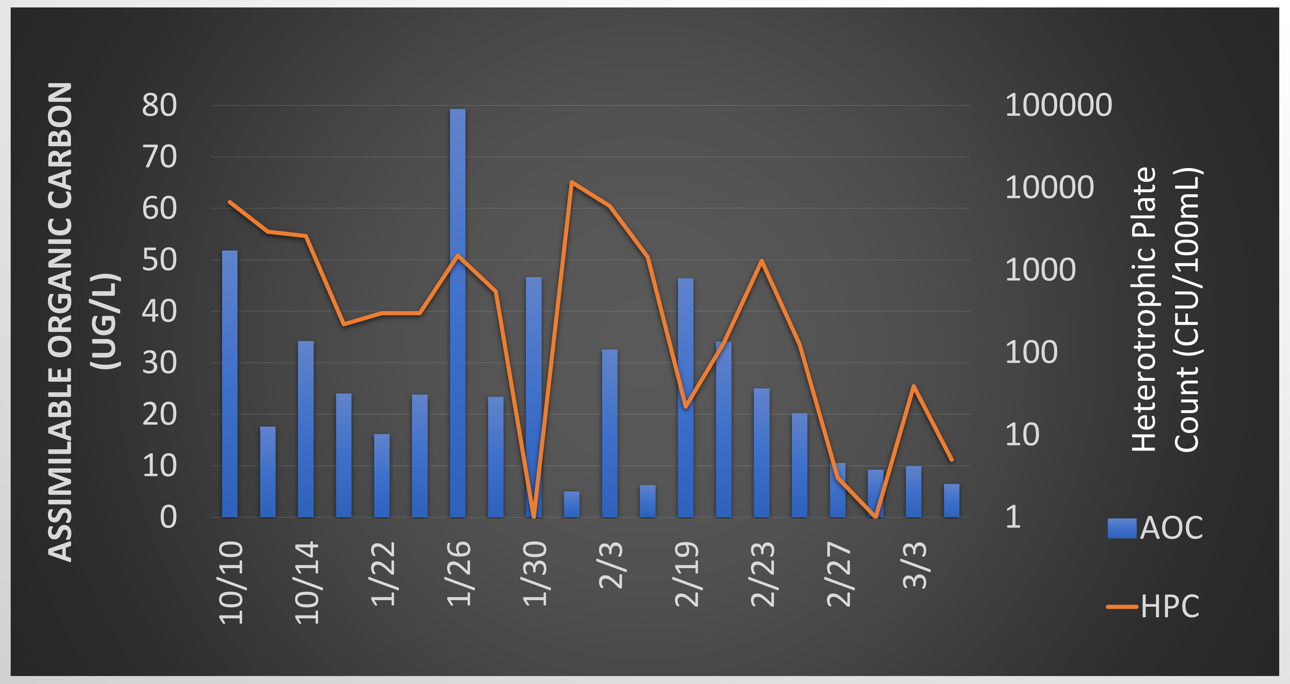


Figure 1: AOC as a predictor of microbial growth in service line

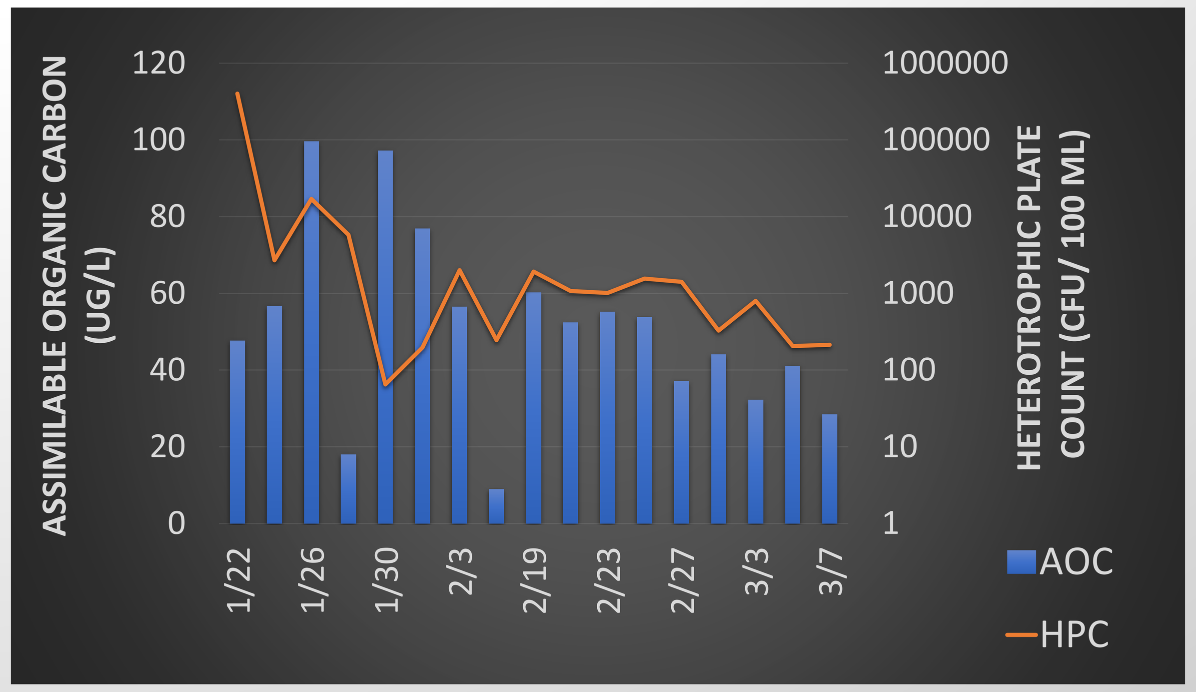


Figure 2: AOC, a predictor of microbial growth in water heater

Preliminary Conclusions

- Mean HPC viable cell counts were substantially greater at the furthest location in the plumbing compared to the service line. Water from hot water fixtures exhibited an order of magnitude greater HPC levels than cold water fixtures.
- Assimilable organic carbon (AOC), a microbial regrowth indicator, ranged from 22.7 - 144.3 µg/L immediately after switching from rainwater to city water, and reduced to 14.8 - 50.9 µg/L for the next sampling period, 3 months after the building was supplied with chlorinated water.
- Nucleic acid staining with flow cytometry indicated that the cells contained 92.7 – 97.9 % low nucleic acid (LNA) cells and 2.14 – 7.29% high nucleic acid (HNA) cells. HNA bacteria are considered larger than LNA bacteria and and actively growing bacteria
- Results indicate rainwater had markedly different microbial characteristics in the plumbing than municipal

Continuing Research

Figure 3: Pilot-scale plumbing rig construction underway

- For municipal water operation, drinking water quality at the service line and in the ReNEWW home is being monitored until September 2018. In October 2018, the system will switch to rainwater and in-building treatment.
- Better understand service line water quality fluctuations through intensive monitoring.
- Develop an integrative hydraulic-water quality model of the home to predict water quality at the tap.
- Conduct pilot scale experiments to evaluate specific phenomena observed in the ReNEWW home.

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