Potable Water Characterization within Premise Plumbing After Transitioning from Municipal Water to Treated Rainwater

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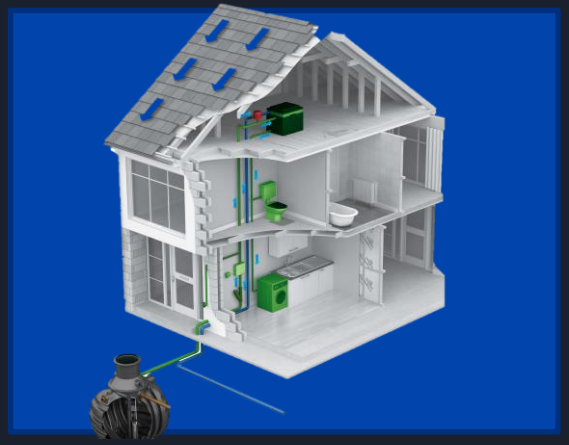
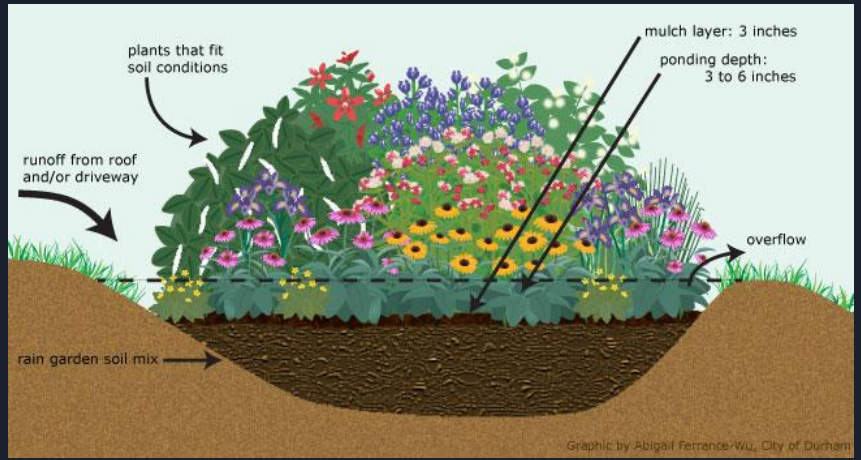
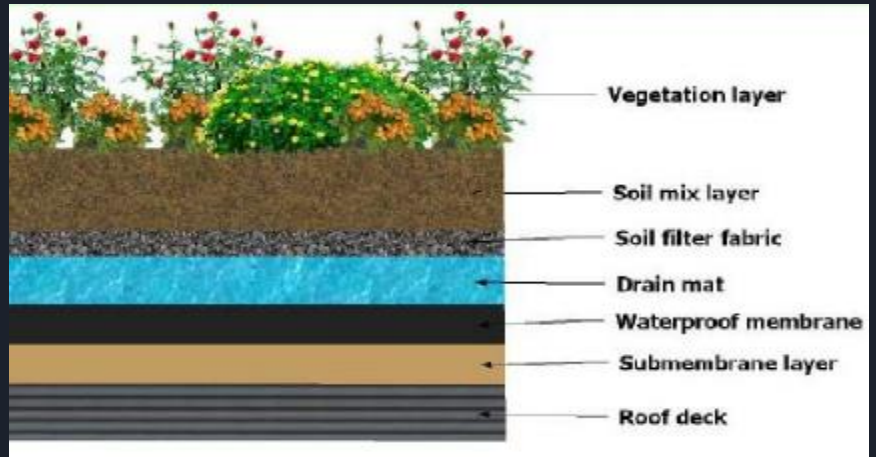
“Green” Urban Stormwater BMPs

- Pervious Pavement
- Rain gardens
- Green roofs
- Rainwater Harvesting





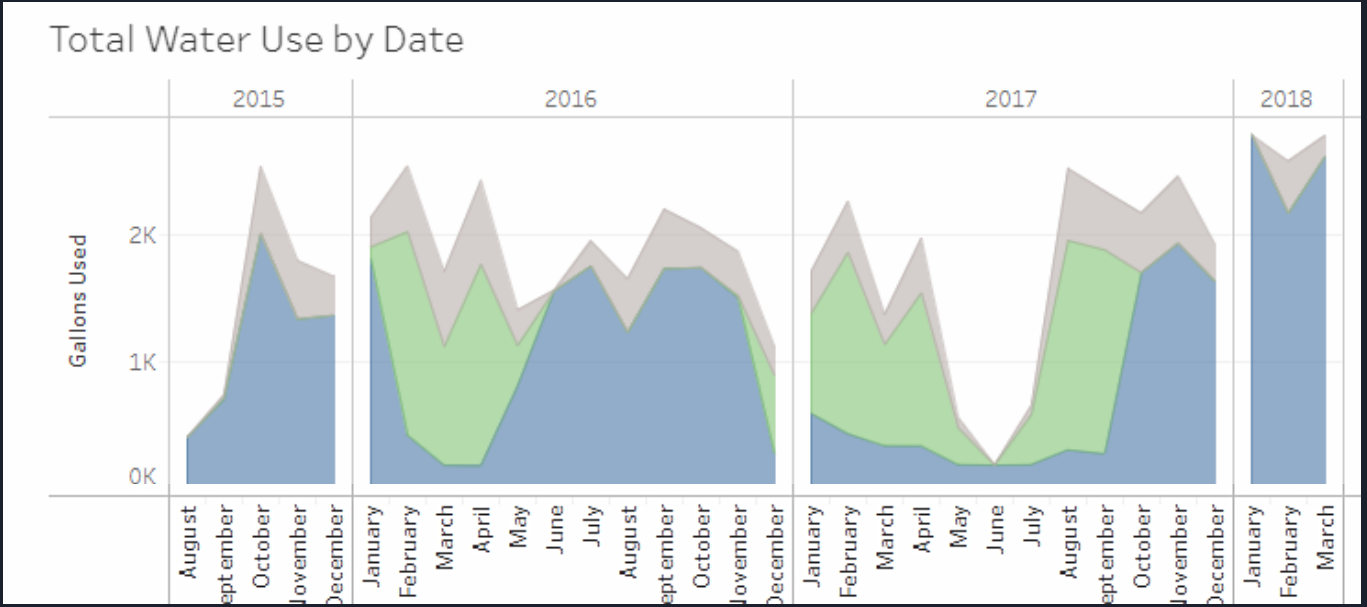


What is the ReNEWW House?

- Solar panels
- Net-zero waste
- Energy efficient appliances
- Rainwater Catchment
- Greywater Recycling
- Flow meters at every fixture

ReNEWW House = Retrofit Net Zero Energy, Water, and Waste

Benefits of Rainwater Catchment



- Reduced runoff to combined sewer overflows, less flooding and erosion
- Lower water bills, 75% reduction in potable water use
- Supplemental water source for irrigation and residential use
- Source: http://www.whirlpoolcorp.com/reneww-house/

Concerns for Rainwater Catchment

- Few regulations, so many rely on Texas Rainwater Harvesting Guide
- Supply > Demand
- Opportunistic pathogens
  - Legionella pneumophila
  - Mycobacterium avium
- Lower pH
  - Corrosive to metal pipes
  - Transition effects scale?
- Longer stagnation times

Why study premise plumbing??

Compared to distribution system pipes, premise plumbing pipes typically have:

- Higher surface area to volume ratios
- Warmer temperatures
- Longer stagnation times
- Rapid chlorine decay rates

Image source: Koets Plumbing, http://www.koetsplumbing.com/water-treatment-systems/agricultural

Experimental Plan

YEAR 1:	Analyze chemical & microbial properties of municipal water
	Constant flow monitoring at every fixture in the home
YEAR 2:	Analyze chemical & microbial properties of rainwater
	Develop integrated and calibrated water quality hydraulic model

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YEAR 1: Experimental Methods

Field Testing

- Temperature
- Chlorine
- pH
- Dissolved Oxygen

Chemical Analysis

- Metals + Ions
- DBPs
- TOC/DOC
- Alkalinity

Microbial Assays

- HPC Culturing
- Flow Cytometry
- qPCR pathogens

YEAR 1: Online Hydraulic Monitoring

Hydraulic Monitoring

- FCS Pressure logger installed at service line
- Omega Flowmeters at every water fixture
    - Flow rate
    - # Events
    - Volume per event

YEAR 1: Field Testing Results

Field Testing

- Temperature
- pH
- Total Chlorine

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

YEAR 1: Chemical Quality Results

Chemical Assays

- **DBPs:** 98.8% of TTHMs are generated within the house (Odimayomi, 2018)
- **Average TOC :** 0.56 mg/L at service line, 0.68 in cold water lines and 0.8 mg/L in hot water lines
- **Lead:** Near 0.0 g/L at service line, and 2.0-5.0 ug/L in hot water tank

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YEAR 1: Microbial Assay results

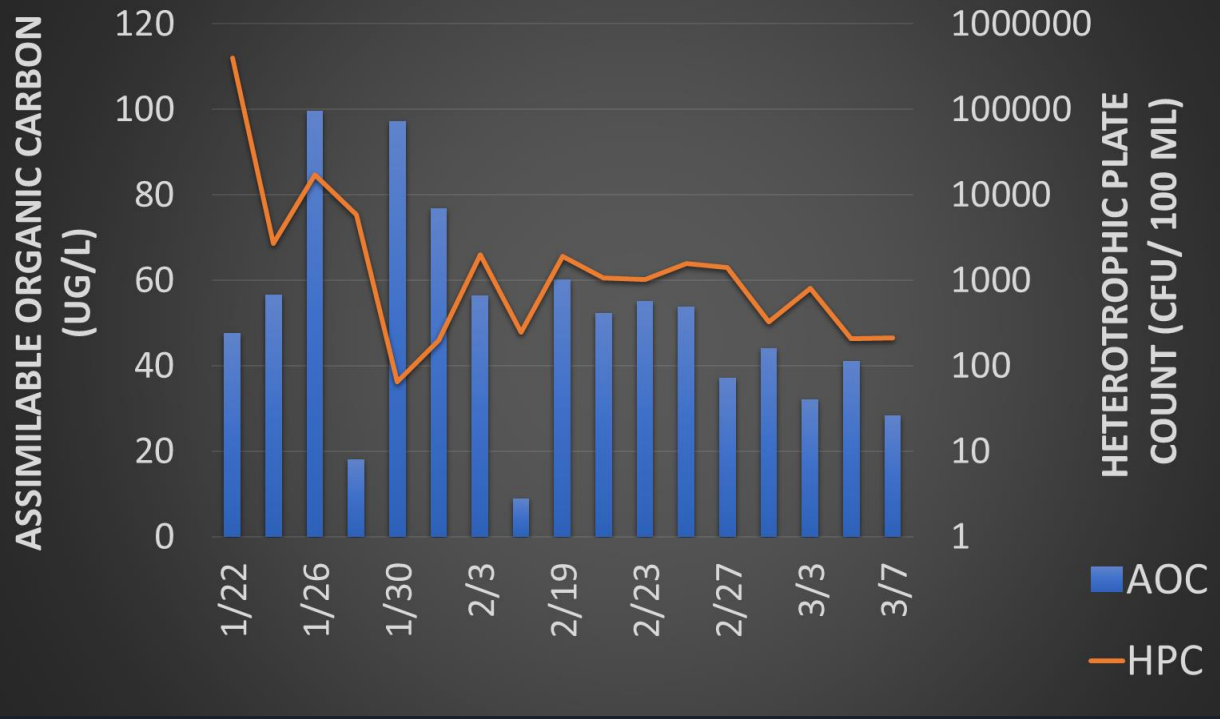
Microbial Assays

- Plate counts
- Flow cytometry
- qPCR- Pathogens

  Legionella spp.

  Mycobacterium spp.

  P. aeruginosa



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YEAR 2: What are we doing next??

Transition back to rainwater and examine effects on water quality

Integrated hydraulic-water quality modeling

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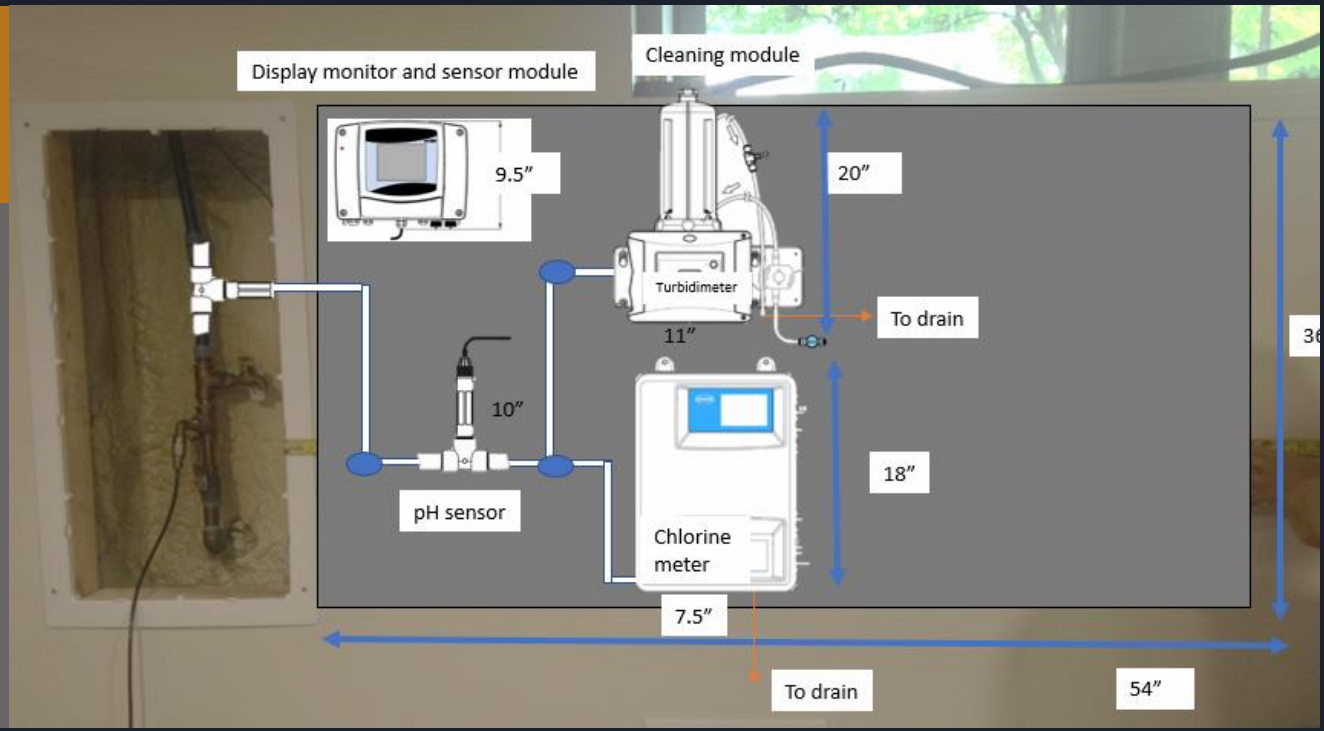
YEAR 1: Online Water Quality Monitoring

Water Quality Monitoring

- Hach system
- Turbidity
- Total+ Free Chlorine
- pH



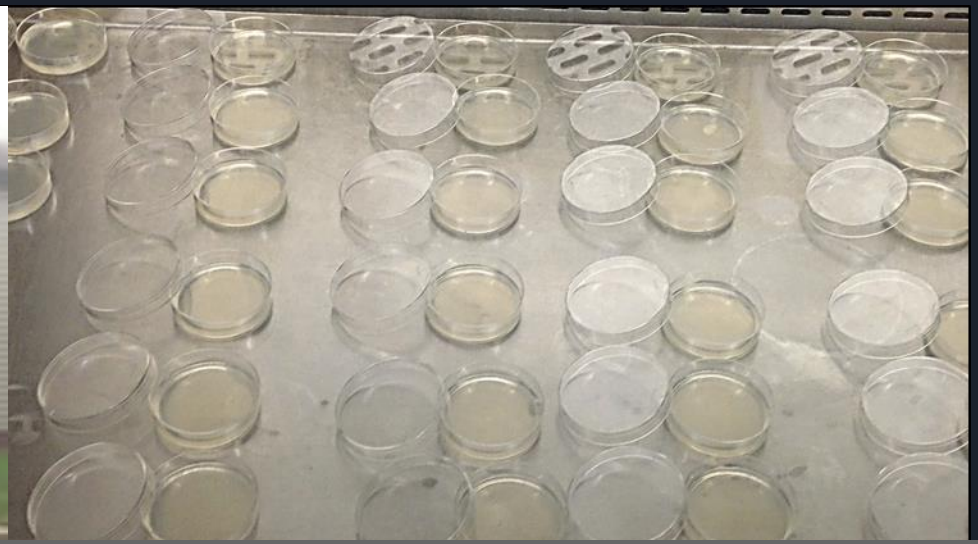
What happens to plumbing after switching to rainwater?

Field Testing

- Substantial pH changes
- No chlorine residual
- Different chemical composition

Pilot Testing

YEAR 2: Transition to Rainwater: Field Testing



OBJECTIVE:

Monitor changes in chemical and microbial water quality after switching house's water supply to filtered and UV-treated rainwater

YEAR 2: Transition to Rainwater: Pilot Testing

COMING SOON:

Pilot scale testing facilities for water quality testing in premise plumbing

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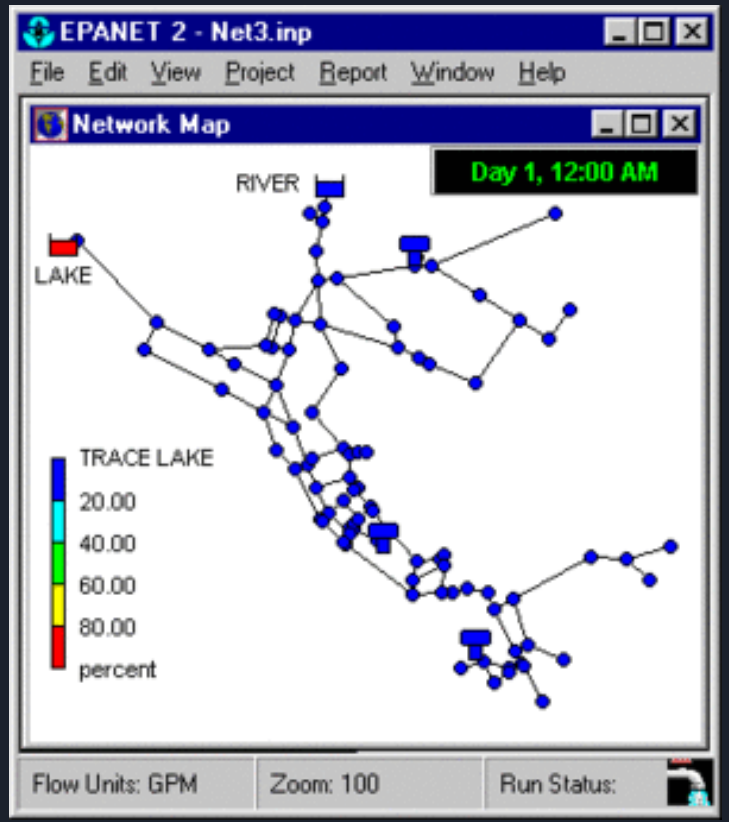
YEAR 2: Integrated Modeling Approach



- Plumbing Network Drawings
- Time Patterns
- Hydraulic Model
- Water Quality Model
- Calibrated Model

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YEAR 2: EPANET: What will the model tell us??

Chlorine Decay

DBP Formation

Microbial Regrowth

- EPANET performs hydraulic and water quality simulations in pipe networks.
- EPANET-MSX (Multi-Species eXtension) models complex chemical and biological reactions

Conclusions

- Water quality data may promote the implementation of rainwater systems in the US
- EPANET hydraulic and water quality simulations will provide useful information for homeowners and other contractors with guidance for rainwater harvesting systems
- Feedback and pilot plumbing test ideas are welcome! Email: cjley@purdue.edu

References

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Image sources

Slide 2:

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Slide 4: http://www.whirlpoolcorp.com/reneww-house/

Slide 5: https://microbewiki.kenyon.edu/index.php/Shower_Head

Slide 6: : Koets Plumbing, http://www.koetsplumbing.com/water-treatment-systems/agricultural

Slide 18: Sheng, 2011