March 29, 2017
TODAY’S TOPIC:
Upcoming Research on the Impacts of Water Conservation on Water Quality in Premise Plumbing

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Ever wonder how water quality is impacted under low flow conditions in buildings and distribution systems? The recent use of low-flow plumbing fixtures such as faucets, toilets, and showerheads has resulted in waterborne disease outbreaks and other water quality problems in building plumbing (premise plumbing) systems. This webinar from two recently awarded National Priorities grantees will describe upcoming research and new science on the impacts of water conservation on water quality in premise plumbing systems. The projects are intended to inform how to better design, renovate, and manage building drinking water systems so that water can be delivered efficiently while protecting public health.
Disclaimer

The views expressed in this presentation are those of the author and do not necessarily reflect the views of the U.S. Environmental Protection Agency. Any mention of trade names or commercial products does not constitute Agency endorsement or recommendation for use.
**Project Team and Scope of Work:** Patrick Gurian, lead principal investigator (PI) working to improve water quality in buildings, will describe the experience of team members and their role in synthesizing knowledge and identifying strategies to protect human health. The presentation will cover the initial scope of work, including key informant interviews and case studies of how water conservation affects water quality in buildings. Information derived from the eventual development of a meta-analysis of the literature will be used to inform a decision support tool for building water management.

**Dr. Patrick Gurian**

Dr. Gurian is an associate professor in the Department of Civil, Architectural, and Environmental Engineering at Drexel University. His research involves the application of mathematical models to evaluate alternative regulatory frameworks and resource management strategies.

**Contact:** plg28@drexel.edu
Experimental Component and Engagement with the Drinking Water Community: Sheldon Masters, co-PI for the effort, will discuss the experimental approach supporting development of the decision support tool. The phases of experiments include bench-scale experiments; experiments investigating on opportunistic pathogen growth; DBP formation potential and energy efficiency; and examination of the impact of pipe materials, water use pattern and water chemistry on pathogen growth and DBP formation using pipe racks.

Dr. Sheldon Masters

Dr. Masters is a Research Engineer at the Environmental Science, Policy and Research Institute and an Environmental Engineer at Corona Environmental Engineering. His work involves field investigations of chemical and microbial contamination in drinking water distribution systems and premise plumbing. Sheldon earned a Ph.D. and M.S. in Civil Engineering from Virginia Tech and a B.A. in Mathematics from The College of Wooster.

Contact: smasters@esprinstitute.org
Water Conservation and Water Quality in Buildings: Research Team and Scope of Work

EPA Webinar
March 29, 2017

Patrick Gurian, Drexel University
Sheldon Masters, Environmental Science, Policy, and Research Institute (ESPRI)
Outline

• Distribution system and building water quality goals and challenges
• Overview of Project
• Team
• Research Plan
Distribution System Water Quality Goals

• Pathogen free water
  o Primary and second disinfection
  o Prevent pathogens from seeding distribution system
  o Control biofilm growth

• Biological stability
  o Reducing regrowth through AOC control
  o Reducing disinfectant decay rates by NOM removal

• Chemical stability
  o Removal of inorganic contaminants
  o Reduce DBP formation

• Non-corrosive water
  o Minimize lead and copper exposure
  o Reduce iron corrosion
  o Better drinking water aesthetics (taste, odor, color)
Primary Causes of Distribution System Water Quality Decay

• Source Water/Treatment Deficiencies

• Chemical/Biological Reactions
  o Bulk water reactions
  o Reactions between water and pipe surfaces

• External intrusion of contaminants

• Poorly maintained storage facilities

• Premise Plumbing Issues

Water Quality Deterioration in Distribution Systems

Why is building water quality unique?

- Buildings have the same WQ issues as the DW DS only to a far greater extent
- High surface to volume ratio due to smaller pipes
  - The greater surface area increases microbial growth, chemical leaching and ultimately higher disinfectant residual decay rates
- High water age
  - More green buildings
  - More low flow fixtures
  - Changing consumer behavior
- Many different types of plumbing materials
- Extreme temperatures
- Low residuals
Water quality in buildings

- Lead
- DBPs
- Opportunistic pathogens
  - *Legionella*
Competing goals

• *Legionella* vs. scalding
• Residual vs. DBPs
• Water quality vs. water conservation
VA Tech study on green buildings (BG) compared to conventional buildings (CB)

• Surveyed four types of buildings:
  – Conventional house (CB- free Cl₂), healthcare suite (GB- monochloramine), net-zero energy house (GB- free Cl₂), net-zero energy/ net-zero water office building (GB- rainwater)

  • Water age: up to 6 months GB vs. 8 days CB
  • Chlorine residual: absent in GB and decaying up to 144x faster than CB
  • OPPPs and 16S rRNA: 1-4 orders of magnitude higher in GB
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conventional (CB)</th>
<th>Healthcare suite</th>
<th>Net-zero energy house</th>
<th>Net-zero energy/water office building (rainwater)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>80 gal water heater</td>
<td>80 gal water heater</td>
<td>160 gal water heater</td>
<td>3000 gal rainwater tank</td>
</tr>
<tr>
<td>Demand</td>
<td>&gt; 300 gpd</td>
<td>0.26 gal/ft(^2)/yr (60x lower than CB; ~7.2 gpd)</td>
<td>65 – 80 gpd</td>
<td>15 – 48 gpd</td>
</tr>
<tr>
<td>Disinfectant residual</td>
<td>Chlorine</td>
<td>Chloramine</td>
<td>Chlorine</td>
<td>None; in-building treatment (filtration, GAC, UV + Cl(_2) 2x/yr)</td>
</tr>
<tr>
<td>Water age</td>
<td>HRT ~1 day in water heater</td>
<td>Average 8 days</td>
<td>HRT = 2.7 days in hot water storage tanks</td>
<td>2-6.7 months</td>
</tr>
<tr>
<td>OPPP</td>
<td>All samples &lt;QL</td>
<td><em>Vermamoeba, Legionella, M. avium</em></td>
<td><em>Vermamoeba, Legionella, M. avium</em></td>
<td><em>Vermamoeba, Legionella, M. avium</em></td>
</tr>
</tbody>
</table>
Overview of Project

• Knowledge synthesis
Research Team: Drexel University

- Drexel University
- Profs. Patrick Gurian, Charles Haas, Mira Olson
- Postdoctoral researcher Kerry Hamilton

- Literature synthesis
- Stakeholder engagement
- Risk assessment
Research Team: University of Colorado

- Professor Scott Summers
- M.S. student Audrey Young

- Experimental studies of water quality in water heaters and pipe loops
- DBP analysis
Environmental Science & Policy Research Institute

- Dr. Sheldon Masters
- Dr. Jennifer Clancy
- Dr. Tom Hargy
- Ms. Randi McCuin
- Dr. Chad Seidel

- Experimental analysis of water quality in water heaters and pipe loops
- Microbiological analyses
- QA/QC lead
Pennsylvania State University

• Professor Stephen Treado
• Doctoral student Changfu Wu

• Modeling of water quality in buildings
• Synthesis of literature information
• Technical resource on building plumbing engineering
Knowledge Synthesis

- Substantial literature on water quality in buildings and laboratory pipe loops
- Often focused on one class of contaminants
- Synthesizing across contaminants is itself a research challenge
- Finding the appropriate threshold for concern is also a research challenge

Prioritizing contaminants in hydraulic fracking flowback water from Abualfaraj et al. 2014.
Reverse Risk Assessment

- Going from risk target to concentration of concern
- What levels of opportunistic pathogens are a concern?
- Use emerging information on dose-response

Deciding when to issue a boil water order for cryptosporidium occurrence from Ryan et al. 2013
Eliciting knowledge from the profession

- Conduct interviews to assemble a set of case studies
- What have utilities, facility managers, and designers been doing to conserve water?
- What have the impacts been?
- Not intended to be a probability sample
  - Exploratory research
  - Understand range of impacts, not precise frequencies
- Knowledge from these case studies needs to be vetted against technical knowledge from the literature synthesis

Galada et al. 2013 expert reports on land application scenarios of concern
Decision Support

- Identify combinations of conditions that are concerns for different outcomes
- High residual, low flow => DBPs
- Low residual, low flow => opportunistic pathogens

- How do we balance these risks?
- What are reasonable tradeoffs?

Preferred bioterrorism response options from Hamilton et al. 2015
Experimental Objectives

• Fill knowledge gaps identified in the literature review

• Assemble a database of premise plumbing conditions and associated health-relevant parameters including opportunistic pathogens, DBPs and corrosion byproducts

• Generate data to parameterize models to predict conditions under which exceedances of health-based levels are likely to happen
Experimental Approach

<table>
<thead>
<tr>
<th>Experiments</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>Bench</td>
<td>• Fill knowledge gaps related to the impact of disinfectants and temperature on opportunistic pathogens inactivation in the bulk water phase</td>
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<tr>
<td>Water heater</td>
<td>• Assess the relationship between water heater types, temperature, water quality and water use on opportunistic pathogen growth and disinfectant by-product formation</td>
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<td></td>
<td>• Data obtained from the experiment will inform the development of statistical models related to water heaters for a web-based decision support tool</td>
</tr>
<tr>
<td>Pipe racks</td>
<td>• Examine the impact of pipe materials, water use, and faucet type on opportunistic pathogen growth and disinfectant by-product formation</td>
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<tr>
<td></td>
<td>• Data obtained from the experiment will inform the development of statistical models related to cold water supply for a web-based decision support tool</td>
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<tr>
<td>Full scale</td>
<td>• Validation of determinist model</td>
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<td></td>
<td>• Scale-up of bench and pilot scale experiments</td>
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</table>
Bench Scale Studies: Opportunistic Pathogen Survival in Under Simulated Water Heater Conditions

• In building water systems there are a range of temp, periods of stagnancy, low residuals
• How do disinfectants perform under these unique conditions?
• The experiment goal is to fill knowledge gaps related to the impact of disinfectants and temperature on opportunistic pathogen inactivation in bulk water
• Focus on disinfectant concentrations and temperatures are typically found in buildings but that have no been previously tested
Water Heater Studies

- Evaluating the impact of water heater type, water use, and water chemistry on water quality and energy efficiency
- Water heater types that will be tested include standard, recirculating, and on-demand heaters
- Pilot experiments will be done in two locations with distinct water qualities (Boulder, CO & Philadelphia, PA)
- Primary concerns
  - Pathogen amplification
  - DBP formation
  - Corrosion byproducts
  - Energy
## Comparison of Representative Water Chemistries

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Boulder, CO</th>
<th>Philadelphia, PA</th>
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</thead>
<tbody>
<tr>
<td>Disinfectant Type</td>
<td>Free Chlorine</td>
<td>Chloramine</td>
</tr>
<tr>
<td>Sodium (ppm)</td>
<td>2.8-4.7</td>
<td>18-111</td>
</tr>
<tr>
<td>Hardness (ppm)</td>
<td>31-167</td>
<td>71-216</td>
</tr>
<tr>
<td>Alkalinity (ppm)</td>
<td>37-45</td>
<td>25-88</td>
</tr>
<tr>
<td>Nitrate (ppm)</td>
<td>&lt;0.2</td>
<td>0.74-4.30 ppm</td>
</tr>
</tbody>
</table>
Pipe Rack Studies

• Pipe materials
  o PVC
  o PEX
  o Copper

• Comparison of representative water chemistries
  o Boulder, CO
  o Philadelphia, PA

• Faucet Type
  o Standard faucet
  o Low flow faucet
Full-Scale Validation

• Deterministic models will be validation and calibrated in at least three full-scale systems
  - NIST net-zero model home
  - Large conventional building
  - Large LEED Platinum building
Other potential experimental considerations

• Additional in-kind participants

• Replicating pilot scale water heater study and pipe rack study in distribution systems that do not use primary disinfection

• Validate and calibrate of models in more buildings
Working Towards Safer Drinking Water at Home, Work, and School: Research to Improve Plumbing Safety: To better understand how unsafe drinking water can occur in buildings, the Purdue research team is developing integrated water quality models and identifying piping network design and operational conditions that can decrease health risks. Andy Whelton, lead PI on this grant will describe the project goals and objectives, ultimately leading to a risk-based decision support tool for building plumbing systems. Dr. Whelton will also describe the wide variety of industrial partners and stakeholders supporting the project and the various roles and backgrounds for the joint Purdue/Michigan State/San Jose State research team.

Dr. Andrew J. Whelton

Dr. Whelton has 15 years of experience as an environmental engineer and is an assistant professor of Purdue University’s Lyles School of Civil Engineering, Division of Environmental and Ecological Engineering. His research efforts have concentrated on the interface of technology, the environment, and public health. He earned a B.S. in Civil Engineering, an M.S. in Environmental Engineering, and a Ph.D. in Civil Engineering from Virginia Tech.

Contact: awhelton@purdue.edu
Right Sizing Tomorrow's Water Systems for Efficiency, Sustainability, & Public Health

Andrew Whelton (PI), Jade Mitchell, Janice Beecher, Joan Rose, Juneseok Lee, Pouyan Nejadhashemi, Erin Dreelin, Tiong Gim Aw, Amisha Shah, Matt Syal, Maryam Salehi

PURDUE UNIVERSITY  MICHIGAN STATE UNIVERSITY  SJSU SAN JOSE STATE UNIVERSITY  Tulane University
plumbing

[ˈplʌmiŋ]  NOUN

the system of pipes, tanks, fittings, and other apparatus required for the drinking water supply, heating, and sanitation in a building

4000-3000 BCE
Copper water pipes in buildings (India)

1500 BCE
Rainwater cisterns (Greece)

500 BCE- 250 AD
Lead & bronze pipes, marble fixtures, gold & silver fittings (Egypt)

1928
First US plumbing code

1966
Copper shortage enabled plastics entry
Premise plumbing is complex

Food Prep Facility

Domestic Hot Water

PEX pipe with copper manifold

Hospital

Cartridge Filters

Copper pipe to cPVC pipe

Some images courtesy of: Gordon & Rasenblatt, LLC
How old is your water before reaching the faucet?

Volume of water stored in pipes

Flowrate of water exiting the Faucet
How old is your water before reaching the faucet?

\[
\frac{\text{Volume of water stored in pipes}}{\text{Flowrate of water exiting the Faucet}}
\]

...our water systems are not designed to handle lower use
Our Project Goal

To better understand and predict water quality and health risks posed by declining water usage and low flows.
Objectives

1. **Improve the public’s understanding of decreased flow** and establish a range of theoretical premise plumbing flow demands from the scientific literature and expert elicitation with our strategic partners.

2. **Elucidate the factors and their interactions that affect drinking water quality** through fate and transport simulation models for residential and commercial buildings.

3. **Create a risk-based decision support tool** to help guide decision makers through the identification of premise plumbing characteristics, operations and maintenance practices that minimize health risks to building inhabitants.
Core Team

PI Whelton
Shah
Salehi

Mitchell
Rose
Beecher
Nejadheshemi
Abouali

Lee
Aw

Dreelin
Syal

Purdue University
SJSU
San José State University
Tulane University
Michigan State University
Our Project was Developed Based on Feedback from the Public, Regulators, Water Utilities, Building Designers, Owners, and Educational Institutions

Core Team Expertise
• Environmental Engineers
• Hydraulics Engineers
• Civil Engineers
• Microbiologists
• Analytical Chemists
• Data Scientists
• Risk Assessors
• Political Scientists

Partners
• Drinking water providers
• Architectural, Plumbing, and Engineering Firms
• Nonprofit organizations
• Educational institutions
• Professional associations
The Project Has 3 Main Objectives

Objective 1. Synthesis Review
Workshop 1

Objective 2. Field & Pilot Studies, Modeling

Objective 3. Decision Support Tool
Workshop 2

Academic Partners
Univ. Cincinnati, USA
Univ. Laval, CAN
Israel Technol. Inst., ISR
Denmark Tech. U, DEN

Design & Consulting Firms
Gordon & Rosenblatt, LLC
Watershed, LLC
CoEngineers, LLC
HRC, Inc.
Inspectapedia
Science Interactive

Government Collaborators
Genesee Co. Health Dept.
NIST
NAVFAC
Army PHC

Association Partners
US Green Building Council
American Society of Plumbing Engineers
National Environmental Health Assoc.
American Water Works Association
Indiana Rural Water Assoc.
Healthy Building Network

Full-Scale Test Sites
ReNEWW Home
LEED Platinum Office Bldg
LEED cert. Middle School
LEED Silver Office Bldg
Renovated Office Bldg

Innovation Partner: Whirlpool Corporation
Yesterday’s Demand, Tomorrow’s Water Systems: Adjusting to Normals: As water fixtures, appliances, and water-use practices have become more efficient, aggregate and per-capita usage has declined. Systems serving legacy cities have seen further declines in the wake of lost economic activity and populations. Due to these and other factors, existing water utility and premise plumbing systems may be oversized relative to needs and pose potential health risks associated with stagnant water. Dr. Beecher will review the planned approach to analyzing and summarizing these trends for the purposes of this study.

Dr. Janice Beecher

Dr. Janice Beecher has served as Director of the Institute of Public Utilities at Michigan State University since 2002. Her areas of interest include regulatory institutions, governance, and pricing, and she specializes in the water sector. She is presently serving on EPA’s Environmental Finance Advisory Board and recently completed service on Michigan’s 21st Century Infrastructure Commission. She has a Ph.D. in Political Science from Northwestern University and faculty appointments in MSU’s College of Social Science, where she has taught graduate courses in public policy and regulation.

Contact: beecher@msu.edu
Aggregate water demand: negative growth rates
Water usage in U.S. cities

Challenge for legacy cities

Loss of population and economic activity

Oversizing and stagnant water
Apparent causes for falling water usage

- Per-connection or per household
  - Demographic shifts (population, household size)
  - Property (lot) size and growth policies
  - Nature of commercial and industrial activities
  - Irrigation efficiency (practices, codes, efficiencies)
  - Effects of recession on economy and income (temporary?)
  - Cost and price effects on discretionary use (elasticity)
  - Aging water meters that under-register (very minor role)

- Per-capita or per-function
  - Efficiency standards (EP Act 1992), codes, and ordinances
  - Commercial and industrial processes an technologies
  - Changing culture and environmental ethic (e.g., lawn watering)

- No offsetting new uses for potable water (unlike energy)
Energy efficiency of home appliances

- Water efficiency standards for toilets, urinals, faucets, and showerheads were established by the National Energy Policy Act of 1992
End-use savings

- Residential End Use Water Study (WRF, 2016)
  - Attributes reductions in household usage to efficiency standards
  - Rather than changes in occupancy patterns or consumer behavior
  - Role of price needs more consideration going forward (discretionary use)
Hyper-efficiency for indoor water usage

• Technological standards could continue to drive indoor usage down
• Hyper-efficiency (<25 gpcd) may have operational consequences
  – Low flows may cause water pressure and quality issues (need for flushing)
  – Low flows also affect wastewater operations (flushing, pressure, or vacuums)
  – Increased use of maintenance water may offset conservation savings
The new normal

- Declining demand of 1-2% annually is not uncommon
  - A nonlinear trend expected to stabilize in the coming decade
  - Saving variable operating costs in short term, capital costs in long term
- Policy implications
  - Upward pressure on rates, need for better forecasting and capital planning
  - Time to reoptimize assets – don’t build tomorrow infrastructure to yesterday’s demand
Dr. Jade Mitchell is an assistant professor in the Biosystems and Agricultural Engineering Department at Michigan State University. Her research broadly focuses on applications of quantitative microbial risk assessment (QMRA) to water quality, food safety and other environmental exposure pathways. Dr. Mitchell obtained a B.S. in Civil and Environmental Engineering from University of Pittsburgh, and an M.S. in Civil Engineering and a Ph.D. in Environmental Engineering from Drexel University.

**Contact:** jade@msu.edu

**Water Microbiology Associated with Plumbing and Health Risks:** Water conservation can lead to low flows and increased water age in distribution systems and premise plumbing. The reduced chlorine residual over time can subsequently allow for microbial growth in drinking water and biofilms along the piping materials. Additionally, organic carbon from certain types of pipes may provide nutrients for increased growth. Dr. Mitchell will review how the synergy among these events contribute to microbial risks, especially those produced by opportunistic pathogens.
Objective 2

Objective 2A
Conduct Full- and Pilot-Scale Testing

Objective 2B
Develop Integrative Hydraulic-Water Quality Predictive Tools that Closely Mimic Residential and Large Buildings

Objective 2C
Predictive Water Quality Modeling to Identify Significant Determinants of Public Health Risk

“Pathogens in plumbing are the primary source of waterborne disease in developed countries”  
*Pruden et al. (2013)*
Opportunistic pathogens

More than 95% of the U.S. population receives drinking water from community water systems.

Ubiquitous in well operated water distribution systems and premise plumbing.
The problem with water that sits

- Leaching of chemicals
- Growth of pathogens
- Sedimentation

The problem with water that flows

- Mobilization of biofilm
- Pathogens
- Sediment
- Contaminants
Biofilms are common in all pipes

Source: Dr. Joan Rose http://www.nature.com/nature/journal/v523/n7562/fig_tab/nature14660_SV1.html
Biofilm niche

- Water distribution systems
  - Low disinfectant residual
  - Warm to hot water temperature
  - Proliferate inside protozoan symbionts
- Showers
- Water faucets
- Humidifiers
- Therapy pools
- Toilets
- Etc.

1) Slough & Detach
2) Aerosolize
   - Droplets & Particles
3) Inhalation

Source: Srijan Aggarwal
Source: Dr. Joan Rose http://www.nature.com/nature/journal/v523/n7562/fig_tab/nature14660_SV1.html
Monitoring
Exposure will be assessed through monitoring in multiple building types and susceptible areas.

HPC, *Psuedomonas, Legionella spp* and *L. pneumophila* and ameoba

- 23s rRNA gene for all *Legionella* spp.
- *mip* gene for *L. pneumophila*
- > 10,000 tests (droplets) per well

**ddPCR Legionella spp. & *L. pneumophila* duplex**

Source: Dr. Joan Rose http://www.nature.com/nature/journal/v523/n7562/fig_tab/nature14660_SV1.html
Bacterial Numbers Increase
10 to 1,000 fold Inside Building Plumbing

Source: Dr. Joan Rose http://www.nature.com/nature/journal/v523/n7562/fig_tab/nature14660_SV1.html
Modeling

EPANET

Regression models
Objective 3

Objective 3a. Risk Model Development

Objective 3b. Decision Support Tool Development
‘Reverse’ QMRA for critical *Legionella* densities – informed Dutch, German & ASHRAE

Critical # in DW
$10^6 - 10^8$ CFU L$^{-1}$
based on QMRA model
Needs hosts to reach that

Aerosolization
Critical # 35 – 3,500 CFU m$^{-3}$
based on QMRA model

Inhalation

Deposition
1-1,000 CFU in lung for potential illness

American Soc Heating, Refrigerating & Air-Conditioning Eng

Source: Dr. Joan Rose http://www.nature.com/nature/journal/v523/n7562/fig_tab/nature14660_SV1.html
OBJ. 2A: FIELD MEASUREMENTS
- Pipe Network Design - pipe sizes, layout, fixtures
- Temperature
- Chemical and Microbial Contaminant Concentrations

OBJ. 1: LITERATURE, PARTNERS, WORKSHOP
- Water Demand, Flow and Use

Water Quality at each fixture
- Water Age – Stagnation time/Residence Time
- Water Quality Parameters:
  - Water pH
  - Alkalinity
  - NOM
  - Disinfectant
  - Larson Index
  - Metal Content

OBJ. 2B EPANET-MSX
- Integrative Hydraulic-Water Quality Models

Bench Scale Experiment
- Model Calibration
- Rate Constants
- Pilot Study
- Field Study

Input
- OBJ. 2B SIMULATIONS – DIFFERENT WATER DEMAND, WATER QUALITY, HYDRAULIC PRESSURES

Output
- OBJ. 2C: WATER QUALITY MODELS
  - Which factors (inputs) significantly influence water quality?
- OBJ. 3A: RISK ASSESSMENT MODELS
  - What are the human health risk associated with the measured and predicted contaminant concentrations?

OBJ. 3B: DECISION SUPPORT TOOL

INPUT

Water Treatment Process
- Well Water
- Lake Water
- River Water

MODEL CALIBRATION

OUTPUT

OBJ. 2A: FIELD MEASUREMENTS
- Water Quality at each fixture
- Water Age – Stagnation time/Residence Time
- Water Quality Parameters:
  - Water pH
  - Alkalinity
  - NOM
  - Disinfectant
  - Larson Index
  - Metal Content

OBJ. 1: LITERATURE, PARTNERS, WORKSHOP
- Water Demand, Flow and Use

Input
- OBJ. 2B SIMULATIONS – DIFFERENT WATER DEMAND, WATER QUALITY, HYDRAULIC PRESSURES

Output
- OBJ. 2C: WATER QUALITY MODELS
  - Which factors (inputs) significantly influence water quality?
- OBJ. 3A: RISK ASSESSMENT MODELS
  - What are the human health risk associated with the measured and predicted contaminant concentrations?

OBJ. 3B: DECISION SUPPORT TOOL
## Schedule of Major Activities

<table>
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<th>Objectives and Activities</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
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</thead>
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<tr>
<td><strong>Obj. 1. Water Conservation Trends</strong></td>
<td></td>
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<tr>
<td>Review &amp; Information Synthesis Workshop</td>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
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<tr>
<td><strong>Obj. 2. Effect of Flow or Water Quality</strong></td>
<td></td>
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<td>Field &amp; Pilot</td>
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<tr>
<td>ReNEWW Home</td>
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<tr>
<td>LEED Platinum Office Bldg</td>
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<tr>
<td>LEED Certified Middle School</td>
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<td>Legacy Office Bldg w/ Renovation</td>
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<tr>
<td>Pilot Exper. to Investigate Field Results</td>
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<tr>
<td>Models</td>
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<td>Database Development</td>
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<td>Analysis of Water Conservation Drivers</td>
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<td>Int. Hydraulic-Fate WDS/Premise Models</td>
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<td>Big Data Water Qual. Regression Analysis</td>
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<td><strong>Obj. 3. Decision Support Tool Development</strong></td>
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<td><strong>Annual EPA Meeting (est.)</strong></td>
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Right Sizing Tomorrow's Water Systems for Efficiency, Sustainability, & Public Health

Questions: Andy Whelton, awhelton@purdue.edu

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Purdue University  Michigan State University  SJSU  San José State University  Tulane University
Plumbing can harbor pathogens

Waterborne diseases in the US
2000-2014

44% at hotels and resorts
19% at long-term care facilities
15% percent at hospitals

Drinking water  Cooling towers  Hot tubs
Top 10 Tips for Your Safety

1. Clean your aerators
2. Do not drink water from a shower
3. Do not drink hot water from a fixture
4. Water heater should be at least 120°F
5. Drain, flush-out your water heater
6. Flush unused faucets before use (i.e., guest bath, vacation)
7. Hotels, motels, hospitals? Flush taps before use
8. Determine what type of drinking water pipes are in your
9. Do you have a lead pipe? Need a water filter
10. When told to flush for a certain time period ask how that
time period was determined

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Building water use has declined