Findings from the

Measurement Science Roadmap Workshop for Water Use Efficiency and Water Quality in Premise Plumbing Systems

Workshop held by the National Institute of Standards and Technology (NIST), U.S. Environmental Protection Agency (USEPA), and Water Research Foundation (WRF)

Presented at the 2019 ACEEE Hot Water Forum by:

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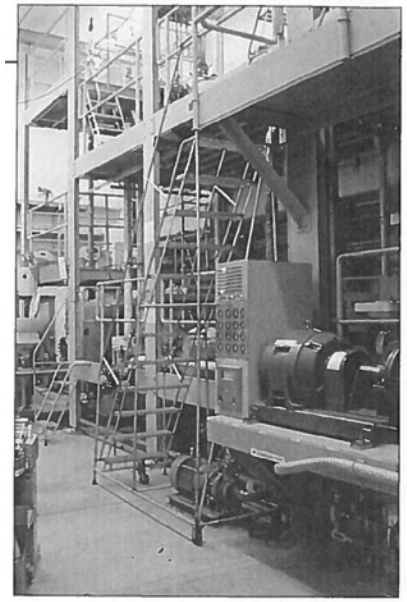
NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Outline

- Background and identified needs
- Workshop purpose, mission and scope
- Pre-workshop activities
- Attendee survey and areas of focus
- Workshop details and structure
- Prioritized research needs
- Future work

Historical Plumbing Research at NIST

- 1924 Need for Minimum Plumbing Requirements
- 1928, 1932 Hoover Plumbing Codes
  - Dr Roy Hunter
  - Hunter Fixture Units
- 1960 Plumbing Tower
  - Test procedures for waste transport
  - Standard recommendations for venting
  - Design improvements for vent design
  - Novel capabilities for transient measurements
- 1978 National Potable Water Conservation Program (HUD)
  - Performance of water-conserving fixtures
  - Water supply requirements for plumbing codes
  - Incorporated into 1983 ANSI standard for water conserving fixtures
- 1990 Dynamic modelling software for plumbing drainage system design



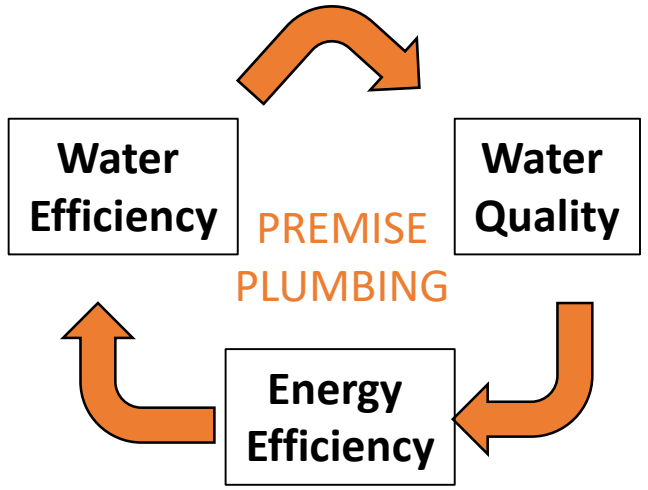
CBT's seven-story plumbing tower and high-speed computerized electronic data acquisition system is used to simulate operation of full-scale plumbing systems in multistory buildings and reduced size venting and drain-waste-vent studies.

(Images courtesy of NIST)

BACKGROUND

Water use and plumbing trends

- Decades old data embodied in building codes
- Indoor household water use increased by 22 % since the 1990s [1,2]
- By 2024, non-draught water shortages in 40 out of 50 states [3]
- National efficiency standards for plumbing fixtures and appliances [4]
- Lower flow rates reducing protective disinfectant residual concentrations, promoting opportunistic waterborne pathogens
- Plumbing design employs new materials with insufficient information
- Distribution, heating, and consumption of water influences energy consumption



BACKGROUND

Additional Issues of Concern

- The need for **updated data and models** to support the design of new premise plumbing systems based on the lower water flow rates, the use of new materials, and the increased awareness of opportunistic pathogens and other water quality issues. These data and models are expected to be implemented through updated design practice and building codes and standards.
- The need for new information to inform the **operation and potential retrofit of existing plumbing systems** that are subject to lower water flow rates than those for which they were designed and which may be affected by degradation in system materials over time.
- The design of **future plumbing systems based on increasing demands** for water efficiency and water quality, employing technologies such as onsite reuse, and different scales of delivery and treatment (from single buildings to campuses).
- The impact of **human factors** such as design, usage patterns, wealth, and locality as they influence water use, system operation, and maintenance. Design also includes retrofit and expansion projects which can affect water quality and system operation.

Steering Committee

WORKSHOP PURPOSE

- Historical Plumbing Research
- Building energy efficiency
- Standards and Codes

- Labeling and certification of water efficient products
- WaterSense labeled homes
- Resources for saving water, energy, and operating costs

- funds, manages, and publishes research on drinking water, wastewater, reuse, and stormwater systems.
- Covers technology, operation, and management

Mission

- To identify and discuss **research needs** to support the design and operation of new premise plumbing systems and the management of existing systems in light of lower water consumption and the need to ensure water quality at the point of use. These needs will be incorporated into a **long-term research agenda** to advance building water use efficiency and water quality.

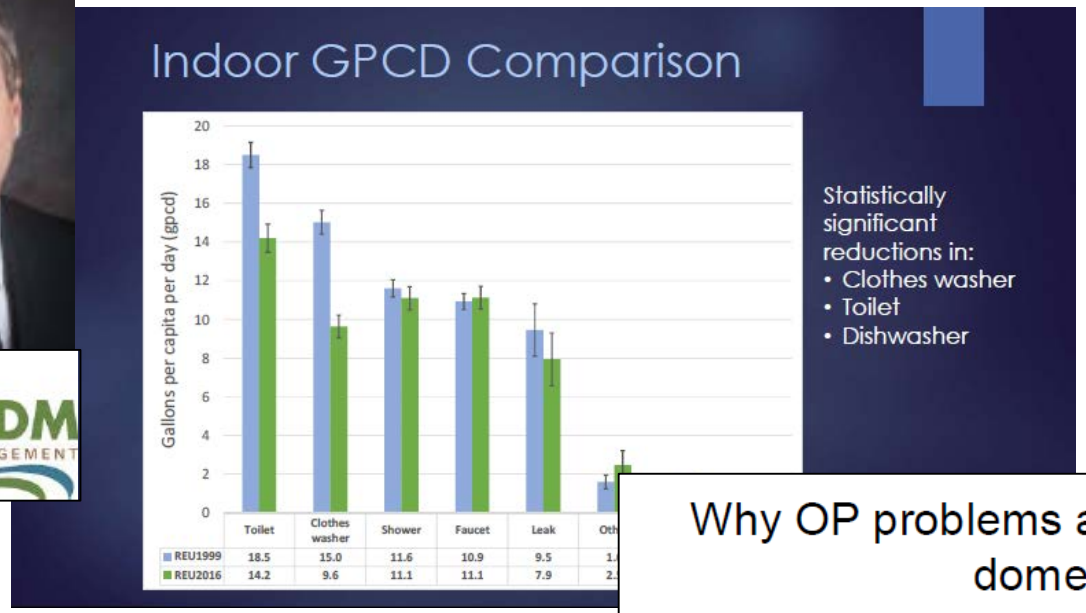
WORKSHOP PURPOSE

Scope

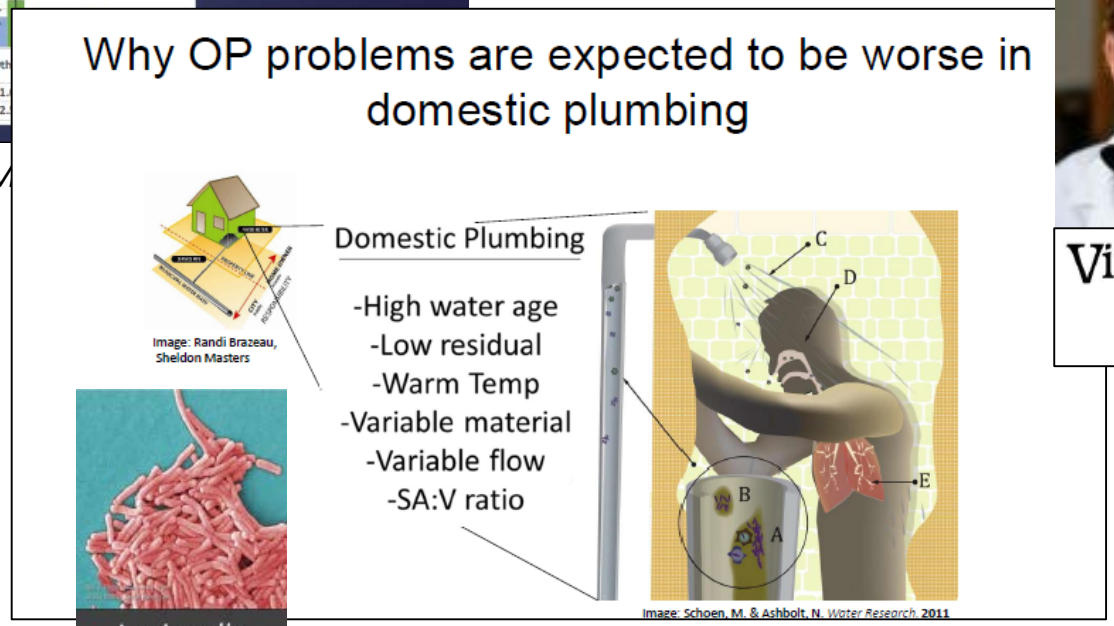
- All **premise plumbing systems in residential, commercial and industrial buildings**, including but not limited to irrigation systems, fire suppression systems, cooling towers, water features, and data centers;
- **Materials used in plumbing systems**, their resistance to corrosion, their ability to maintain structural integrity, and their interaction with contaminants and treatment chemicals;
- The **physical attributes** of the plumbing system, including pipe diameter, length, and presence of features that result in stagnation (i.e., dead-legs);
- System **operation and maintenance and occupant water use**;
- Water quality conditions at point of entry into the building and the **change in the quality of water** before its on-site point of use; and
- **Data needed** for design and operation, including water demand assumptions.

Introductory Webinar Hosted By EPA WaterSense

WaterDM
DEMAND MANAGEMENT



(Images courtesy of Pete M



Legionella pneumophila

Virginia Tech

(Images courtesy of Prof. Marc Edwards, VT)

Pre-Workshop Questionnaire

1. Do you have any feedback on the core issues and scope identified in the two-page background document?
2. What do you see as the **three most important drivers** that are impacting the design and operation of premise plumbing systems?
3. Are there **specific areas where you believe current data, modeling tools, standards/codes, and guidance materials are lacking** in their ability to support the design and operation of premise plumbing systems?
4. What you see as the **three most important research needs** to support the design and operation of premise plumbing systems?
5. Do you know of any key resources that would inform development of a research agenda?

Responses: Drivers

- There has been an **increase in incidents and outbreaks related to OPPPs** in recent years, resulting in more attention to disease prevention and water quality in buildings.
- The U.S. has **aging water and wastewater infrastructure** that is in need of reinvestment and renewal. At the same time, an aging building stock exists and continues to grow. Legacy issues persist from old plumbing system materials and new issues continue to arise as water use behavior and operation and maintenance recommendations change.
- **Differences in source water create differences in water quality and biological characteristics.** For example, some regions are beginning to depend more on surface water, which has different biological characteristics than groundwater.
- Material, design, and installation preferences of architects, plumbing designers, home builders, plumbers and contractors may impact **systems operation**. These professionals are continuing to use **older techniques**, perpetuating poor plumbing design, installation, and operation.
- **The designer, builder, and end-user communities do not necessarily have the resources and tools** to fully understand premise plumbing issues.

Research Areas of Focus

1. Water usage patterns and end uses in commercial and residential plumbing as they relate to system design and pipe sizing
2. Impacts of pipe material and installation on the long-term condition of the plumbing system
3. Impact of water use/flow rate/water velocity on water quality and biofilm growth
4. ~~Efficacy of water management and/or treatment strategies for maintaining water quality~~

Structure

- Held: August 1- 2, 2018 at NIST, Gaithersburg MD campus
- 45 stakeholder attendees: industry, academia, government, utilities, standards and codes orgs, and research orgs
- Two groups, 4 break-out sessions to cover
  - **Research Area 1:** Water usage patterns and end uses
  - **Research Area 2:** Impact of piping materials, design, and installation
  - **Research Area 3:** Impacts of water use/velocity/flow rate/residence time on quality, biofilm, and scale growth
- Prepopulated tables of research priorities; tasks were to add and provide rationale to larger group
- **48 research priorities were identified, ranked, and dependencies determined**

Prioritization of Research Topics

RESEARCH NEEDS

Table 1. Prioritized Research Topics From Workshop Discussion

	Research Topic Description	Rationale	Related Research
1	Water quality: How do materials impact water quality (biological and chemical) over the typical lifetime of the plumbing system? (In other words, does material selection and quality impact water quality of the premise plumbing?) Do the age, condition, and type (e.g., materials, fixtures) impact the growth and persistence of OPPPs (inactivation)? Biological and chemical impacts are considered holistically with the recognition that they can be researched independently.	This is a fundamental, all-inclusive research topic.	Related to topic #3, #5, #10, #14
2	Need data to better understand occupant behavior and water usage patterns for different residential and commercial building types (sequence research based on primary-use types and building types with vulnerable populations [e.g., hospitals, healthcare, daycare, and senior living]).	This is a foundational piece for establishing data, without which mistakes will be made. The success of other research items is highly dependent on this item. Current data are not consistent enough to allow comparability across buildings. Addressing this need provides a basis for understanding water turnover and efficiency factors at reduced construction cost. The research scope should not be limited to building structures and can include campuses (any point after main meter). Information can be used to reduce supply, sewer, and branch pipe sizing. Collect data at all spatial and temporal scales. Current data are lacking to inform new water demand models and improve codes. Other research needs and model development are dependent on progress in this area. **POSSIBLE SUBTOPIC:** How can new construction be used as part of data gathering (installing devices to help monitor water use/demands)?	
3	Hunter's curve needs updating, or alternatives to Hunter's Curve need development (IPC/UPC needs to reflect current and future trends in terms of low flows). Alternative sizing models (Water Demand Calculator) need to be validated and potentially improved to establish minimum and maximum pipe sizing (based on data).	Once data are collected and a new methodology is established, this item will support code revisions that will impact new building design. Codes are the primary basis for designs used by engineers and contractors. By evaluating the water demand calculator, it will provide a shortcut to other research items. The methodology used to establish Hunter's Curves considered flow rates from 80-100 years ago and is also labeled for residential only. **POSSIBLE SUBTOPIC**: How do we design systems that can operate effectively at both minimum and peak flows?	Requires data input from research topic #1. Related to #5

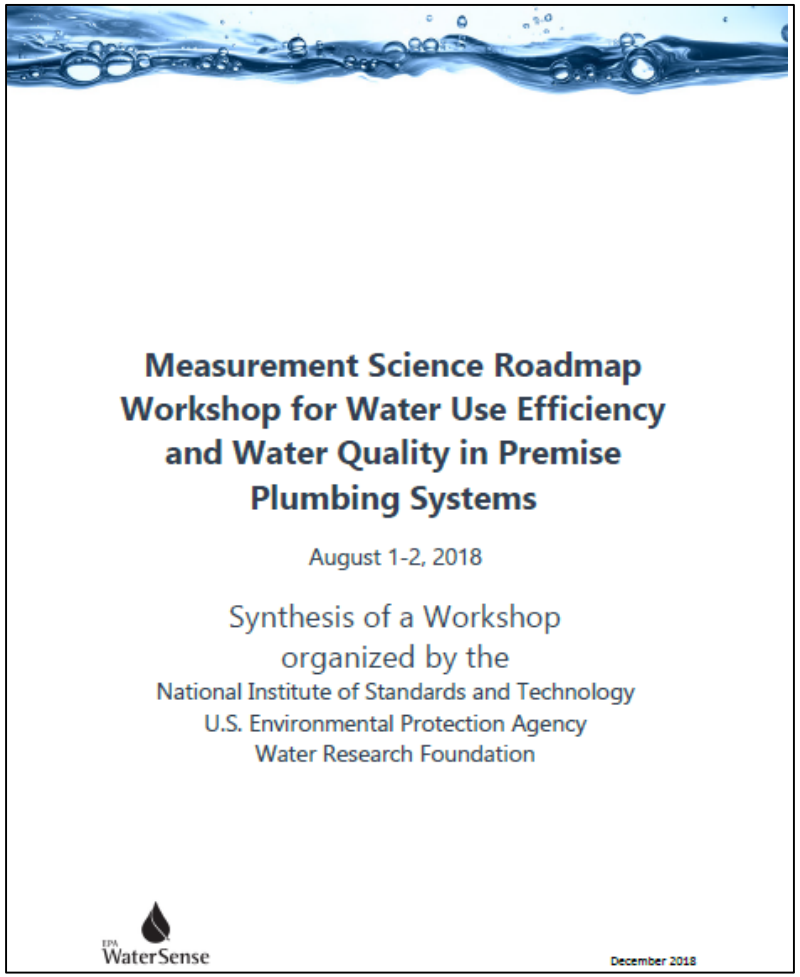
Prioritization of Research Topics (cont.)

RESEARCH NEEDS

	Research Topic Description	Rationale	Related Research
4	How do factors (physical factors such as pressure and system age and operational factors such as water age/stagnation, flow rate, water velocity, and water temperature) impact biofilm and scale and its impact on water quality within different materials (considering factors such as growth rates, type of biofilm, general biofilm characteristics, and ecology)?	Biofilms and scale are important because they are major drivers for quality problems. Biofilms and water quality are not interchangeable, and this research area brings in factors that evaluate how biofilms impact water quality. Biofilms are always in contact with water and on the premise, so they have a potentially large impact on water. Biofilms harbor pathogens and protect them from disinfectants, so it is critical to understand biofilms. New and innovative products and conservation drastically change the way our systems perform, and we need to understand impacts. Because this research item is difficult to study, it hasn't yet been done, but it's important for the future. An important consideration is the type of material of the incoming pipe and its impact on water quality and pressure.	Related to #25
5	System performance: What is the impact of public/well/alternate source water quality (e.g., biological, chemical, disinfectant or lack thereof, physical) on the performance of the entire premise plumbing system materials and subsequent water quality over the typical lifetime of the system? (Acknowledging difference between water quality entering the building and changes that occur in the building itself, including in-building treatment).	The reverse of Priority Area 1. All-inclusive.	
6	Develop a greater understanding of how water demand patterns impact water quality within premise plumbing systems.	Usage information is critical to assess real-world impact. Laboratory outcomes must be compared with real-world outcomes to fully understand risk. This topic is fundamental. Design is unlikely to dictate behavior to people (e.g., when you use the restroom), so it is important to understand behavior and design accordingly. Design is currently based on outdated behavior patterns. There is a need to understand use patterns, not just water quality, and its impact on code. Hypothesis: Use is much smaller than thought and intermittency is higher (at least for residential, may differ in commercial). There is a need to understand if this is true and its impact. **POSSIBLE SUBTOPIC:** What is the water quality at the service line versus at each outlet within the premise plumbing, and how is this impacted by usage patterns?	Related to #3

Where you can find the workshop synthesis report

- https://nvlpubs.nist.gov/nistpubs/gcr/2019/NIST.GCR.19-020.pdf



Key Take-Aways: Three Over-arching Categories

RESEARCH NEEDS

Water Use Data (Research Topics 2, 6, 12, 18, 32, 44, 45, and 46)

Workshop participants saw a need for additional data on how water is being used in different types of residential and commercial buildings. There is a need for national, accessible, and consistently compiled databases that can provide a foundation for research efforts. In addition to data that reflect the types of uses and/or fixtures, it is also important to have more data on how occupant behavior influences water use.

New Ways of Thinking About Design (Research Topics 3, 11, 19, 21, and 48)

There was agreement that the models that influence plumbing system designs need be updated to reflect present-day water demand patterns and the integration of newer, more complex technology into the built environment. Designers, practicing professionals, and incoming students also need guidance to help them maintain existing and design new plumbing systems.

Understanding Changes in Input Water Quality in Premise Plumbing to Determine Starting Point (Research Topics 1, 3, 5, 6, 7, 22, 35, 36, and 42)

Workshop participants agreed that there needs to be a better understanding of the interactions between water quality and premise plumbing. There is a need for more integrated and interdisciplinary projects that consider the influence of water quality on premise plumbing materials and vice versa and how design or water use patterns influence biological and chemical quality of water.

Key Take-Aways: Cross-cutting Themes

RESEARCH NEEDS

Standardization

Standard definitions needed to create a shared understanding and common language. There also needs to be a standard protocol for measuring, reporting and archiving water use (demand) readings taken at all types of premise plumbing systems. Participants also advocated for widening the lens from single-family homes to include large and complex building systems. Workgroup participants indicated that research topics related to standardization were fundamental, without which the research agenda would fail to achieve its intended impact.

Existing Data

Existing data should be used to shortcut or accelerate some of the identified research topics. Specifically, participants noted that residential data are available, while data in other sectors, such as commercial, may not be available at present.

Sequential Research Needs

Workshop participants discussed the different types of end products across research topics. For some research topics, such as Topics 11 and 16, the end product may be a guidance document, and these types of products may need to be sequenced after research into best practices has been completed.

Key Take-Aways: Reflections

- Holistic Approach
- Risk and Recommendation Communications
- Impact to Disadvantaged Communities
- Industry Communication
- The Cost of Inaction
- Definition of Water Quality

Future work

- Incorporate workshop findings with requested public input via Federal Register Notice (83 FR 50897): “Request for Information Regarding Measurement Science Needs for Water Use Efficiency and Water Quality in Premise Plumbing Systems”
- Develop Roadmap Document for long-term research guidance
- Disseminate!


QUESTIONS