Adaptive Flushing of Building Drinking Water Taps Using Real-Time Oxidation-Reduction Potential (ORP) and Temperature Signals

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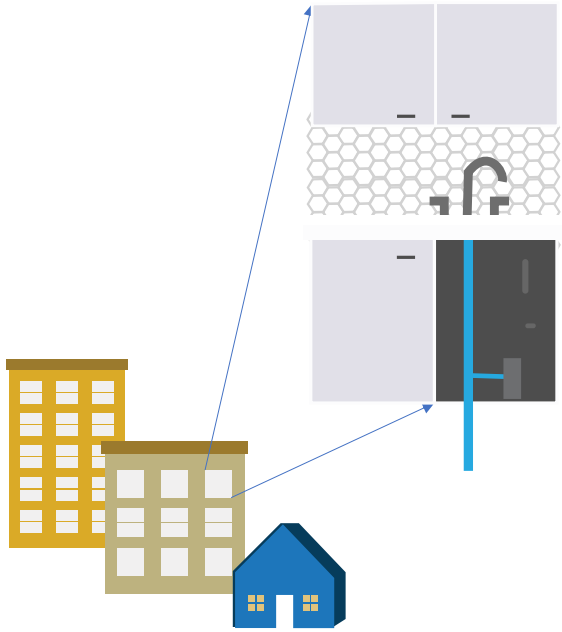
Environmental Biotechnology Lab

Real-Time Water Systems Lab

Building plumbing causes detrimental effects to drinking water quality. Flushing is a solution.



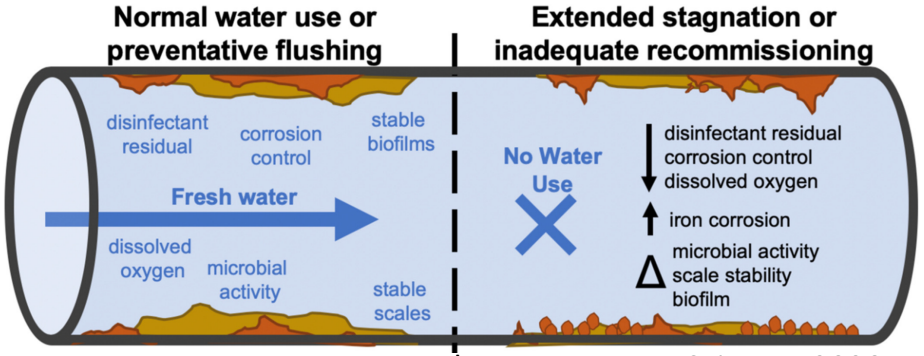
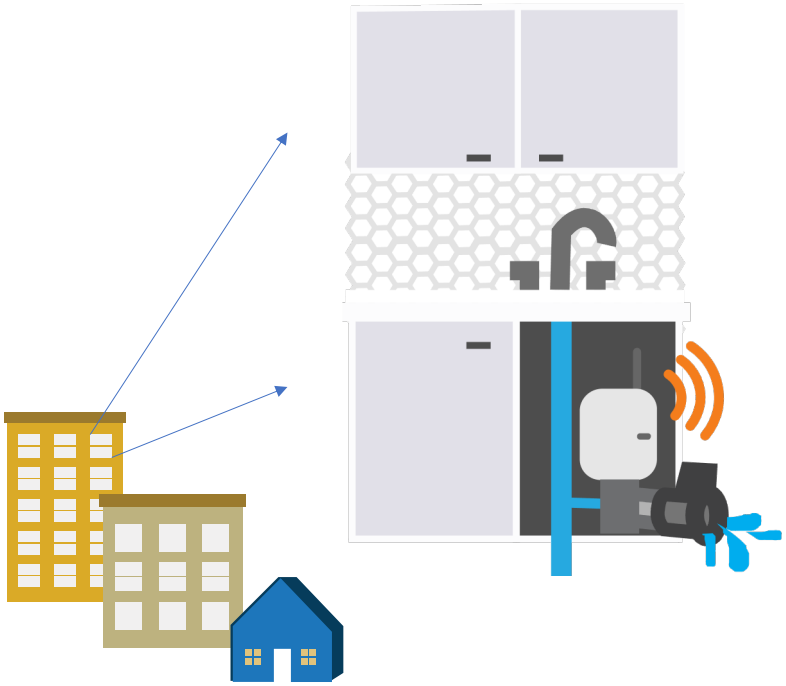
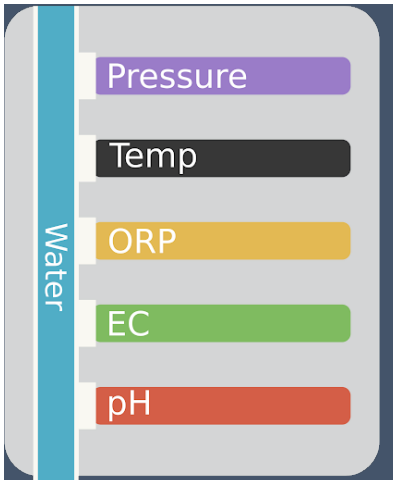


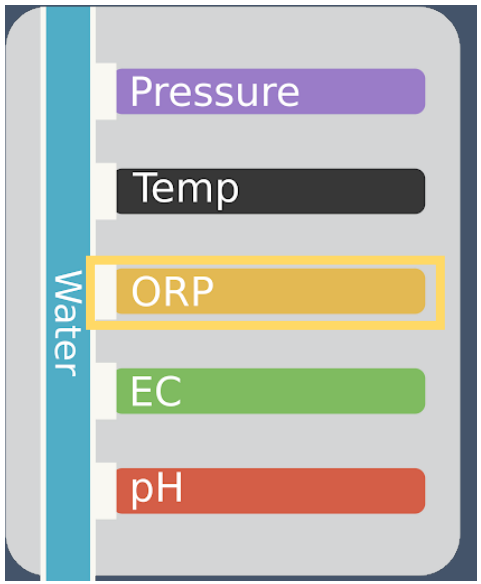
Image source: Proctor et al. AWWA Water Science. 2020.

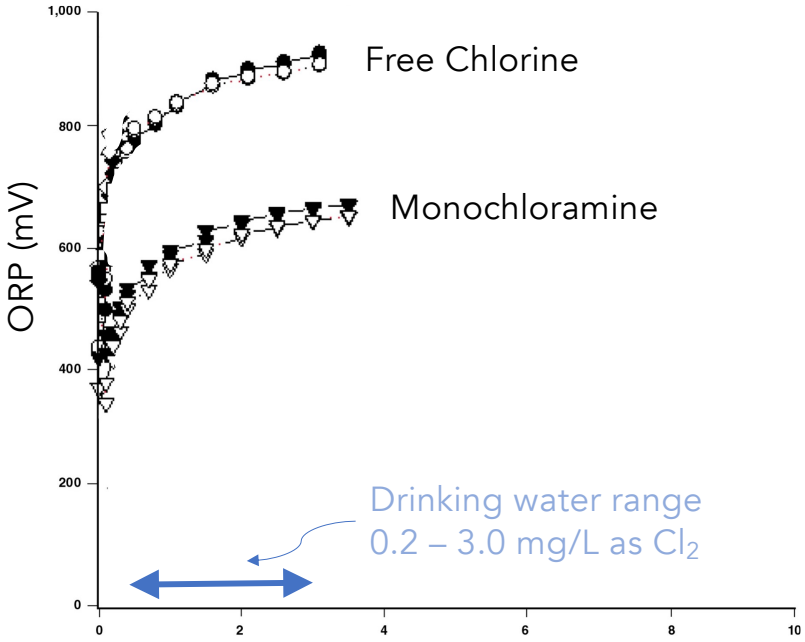
Real-time sensing at the tap will inform automatic flushing to maintain healthy water





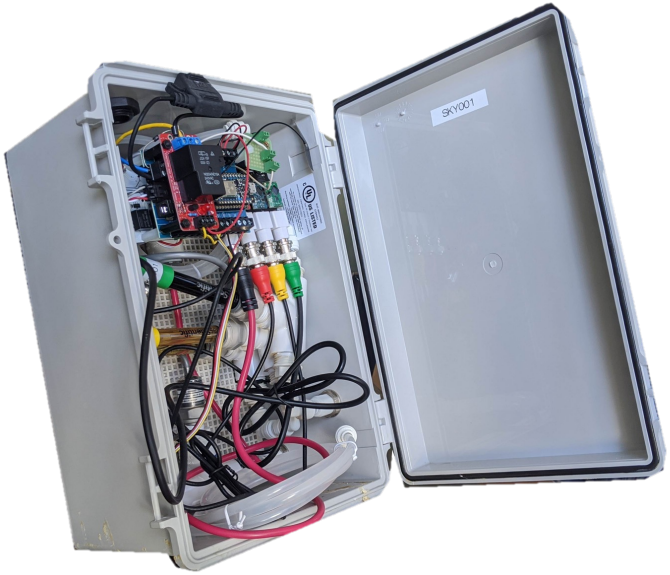
Oxidation-Reduction Potential (ORP) correlates to disinfectant concentrations in drinking water.



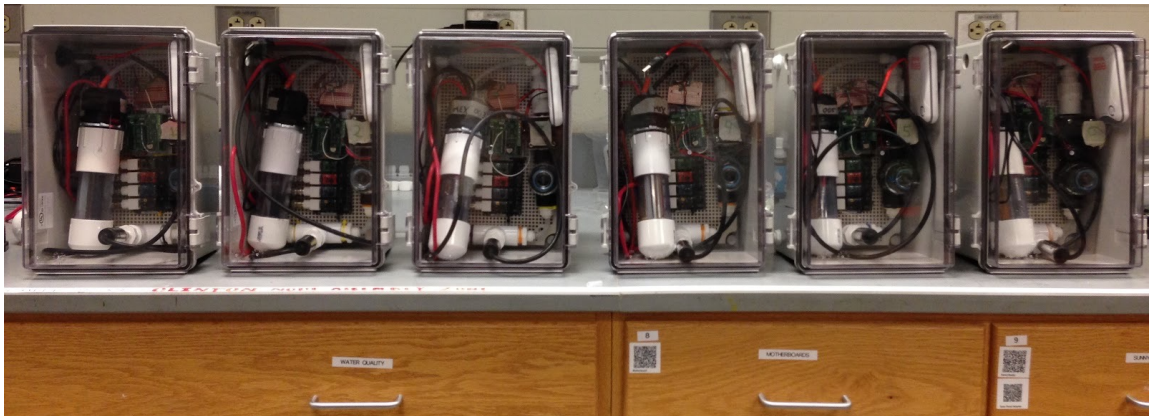


Source: Copeland and Lytle, 2014

We designed and built custom sensor nodes to deploy in taps and measure water quality in real time

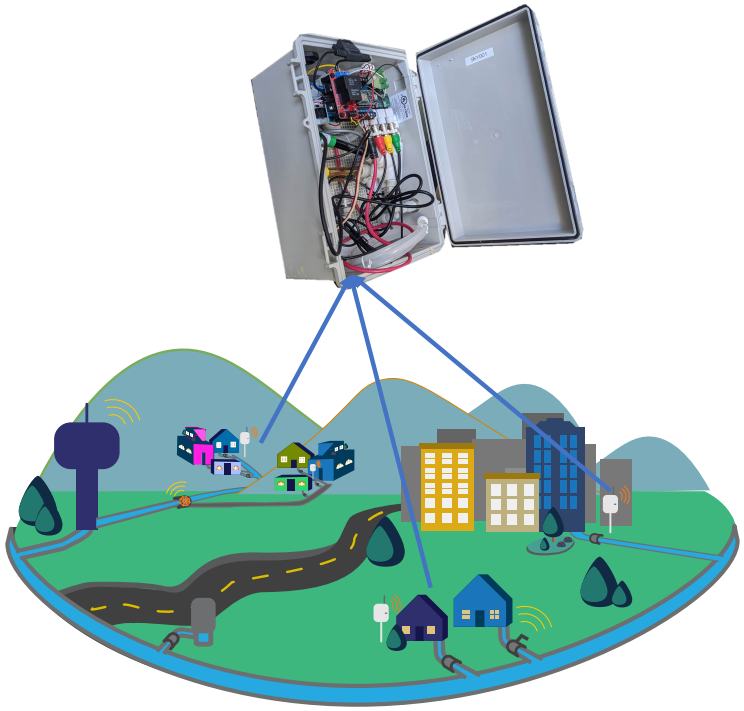


*Not actual size

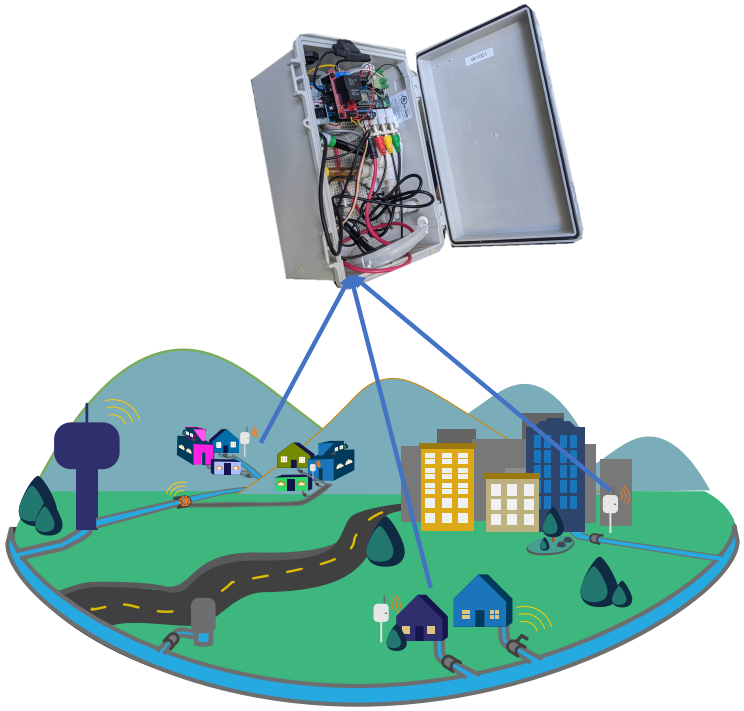


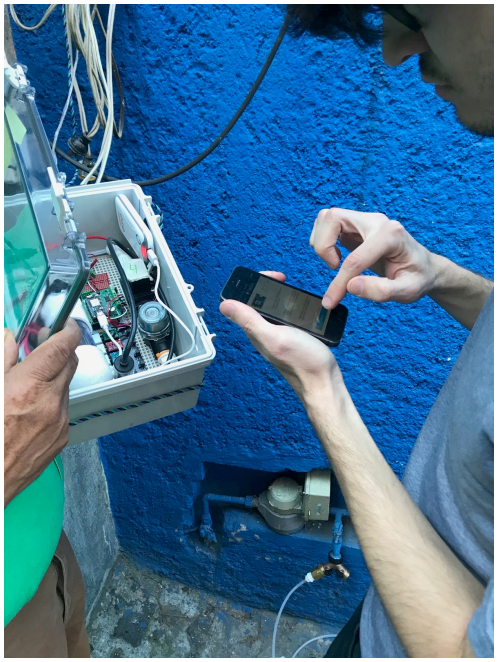
Github.com/kLabUM/DrinkingWaterNodes

Deployed nodes at more than 30 households directly at the taps in Ann Arbor and Mexico City

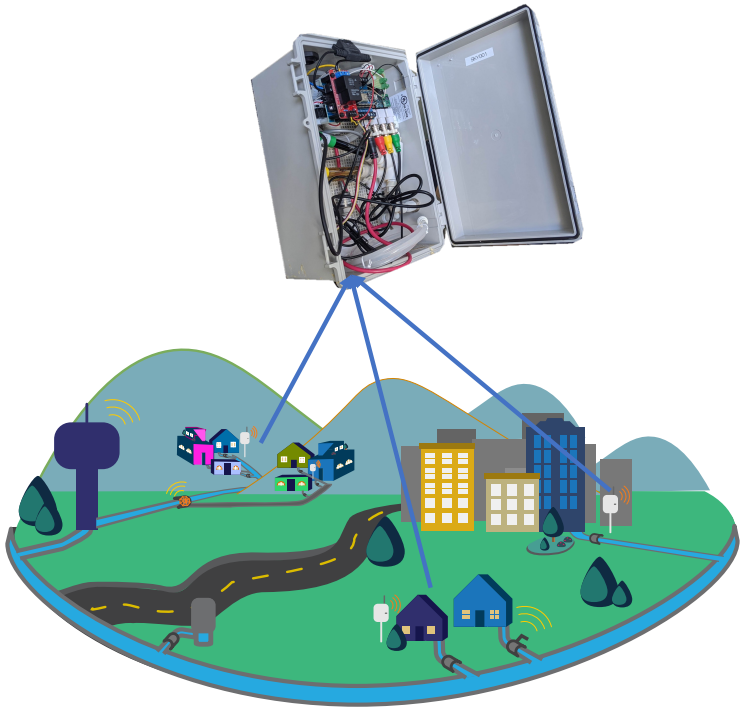


We deployed at more than 30 households directly at the taps in Ann Arbor and Mexico City

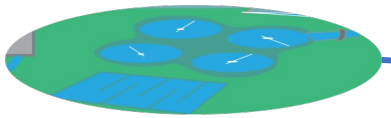




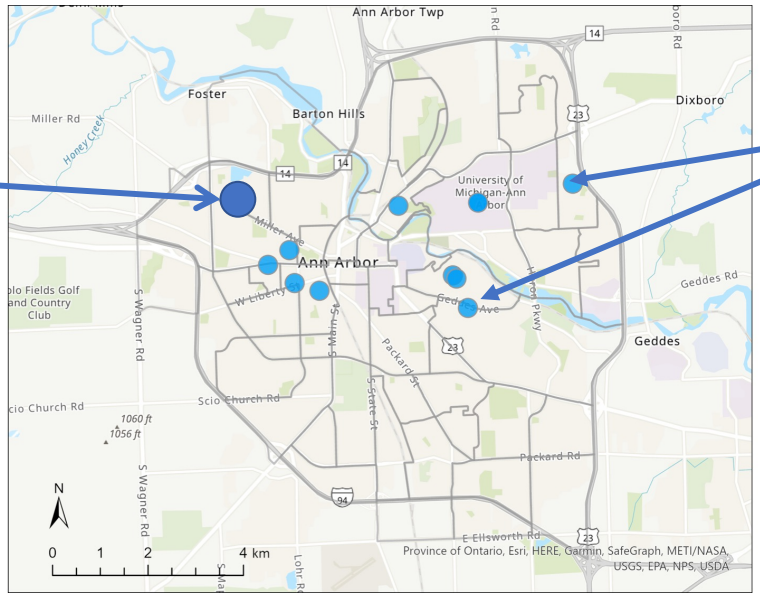
We deployed at more than 30 households directly at the taps in Ann Arbor and Mexico City



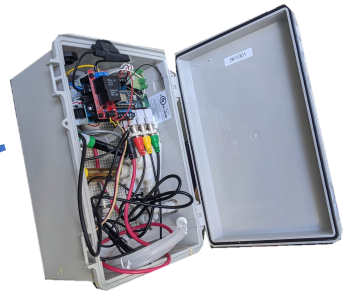
Ann Arbor uses chloramine as a residual disinfectant and is a homogenous system, so we expect same water quality



1 treatment plant for 120,000 people

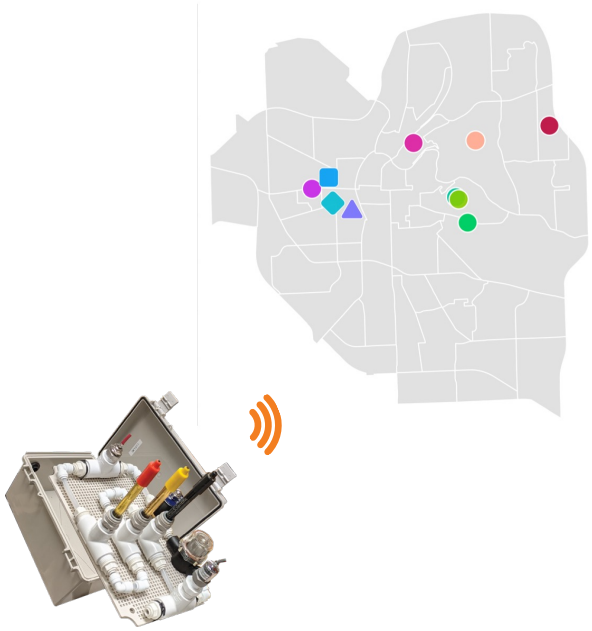


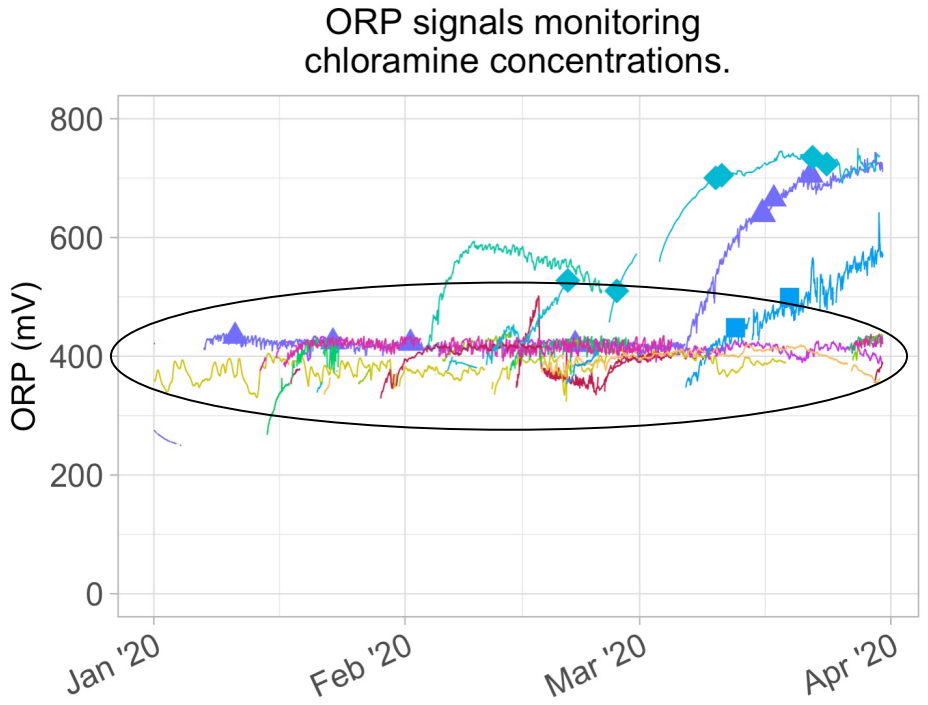
Ann Arbor, Michigan, USA



Deployment sites.

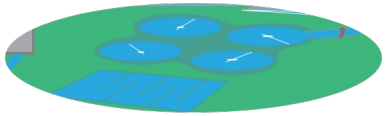
ORP signals from Ann Arbor measuring adequate chloramine levels in drinking water and capturing spatial trends.



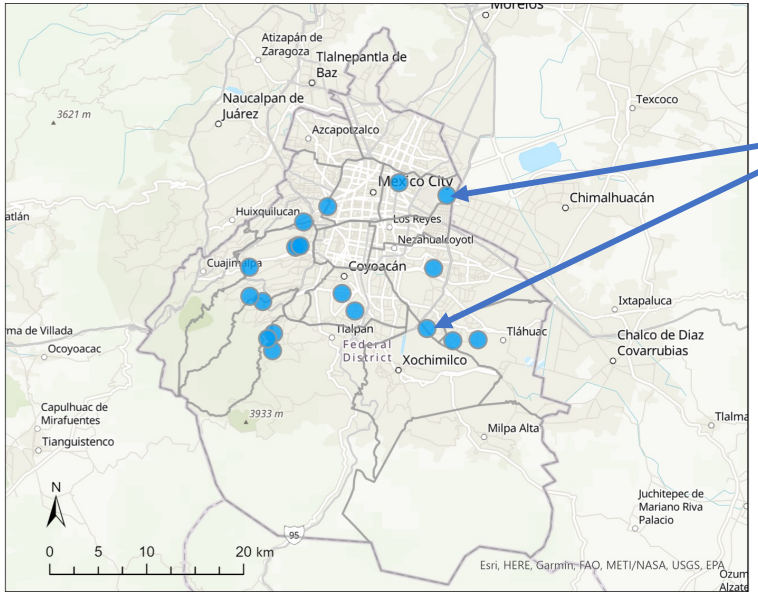


Martinez-Paz et al. ES&T Engineering. 2021

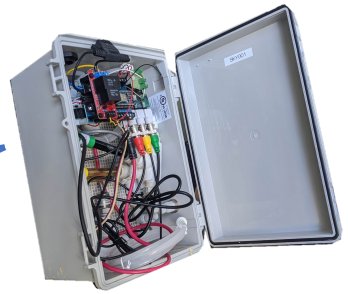
Mexico City uses free chlorine as a residual disinfectant and is a heterogeneous system, unsure what to expect



58 Treatment Plants for 9M people

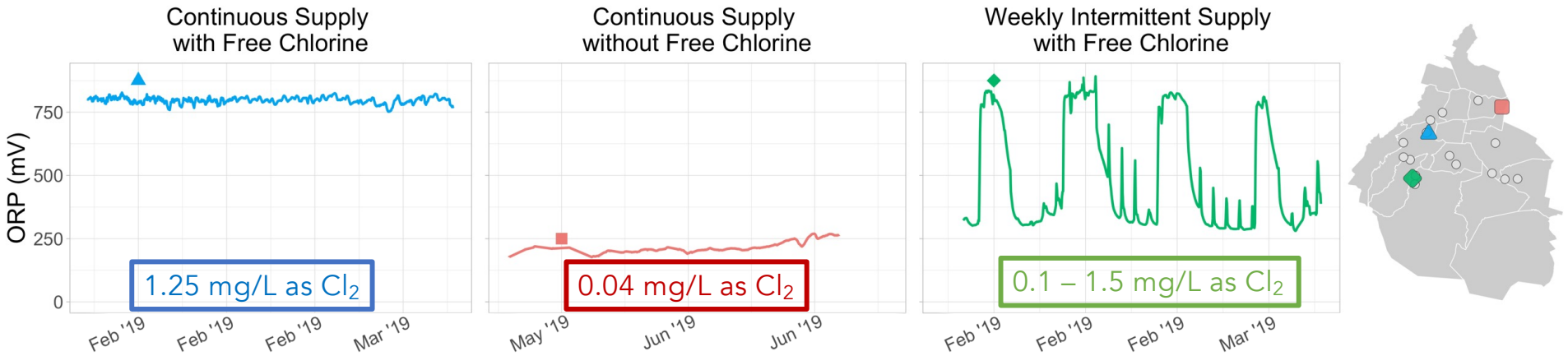


Mexico City, Mexico



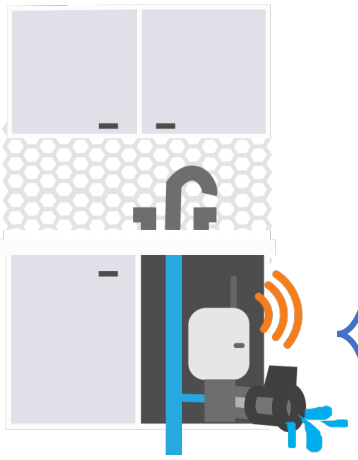
Deployment sites.

Differences in ORP signals from Mexico City highlight water quality is not the same.



Martinez-Paz et al. ES&T Engineering. 2021

Can real-time ORP sensing can be used to actuate wireless valves and rationally flush building tap water

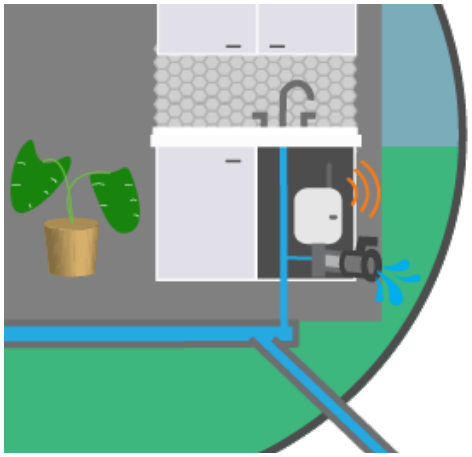


Real-time ORP

Wireless valve

Better water quality

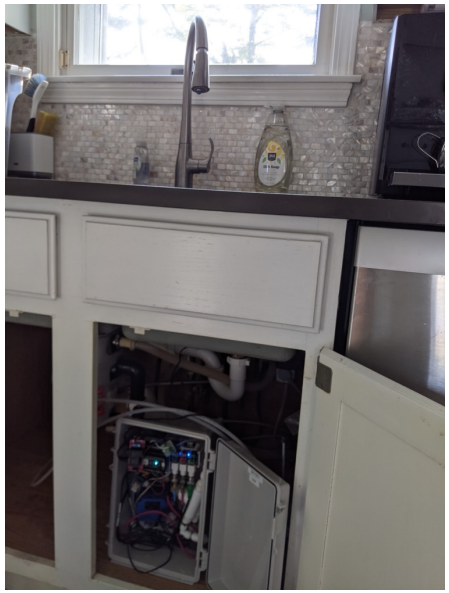
I compare different flushing approaches experimentally to determine how this technology application may look like

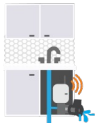


No Flushing

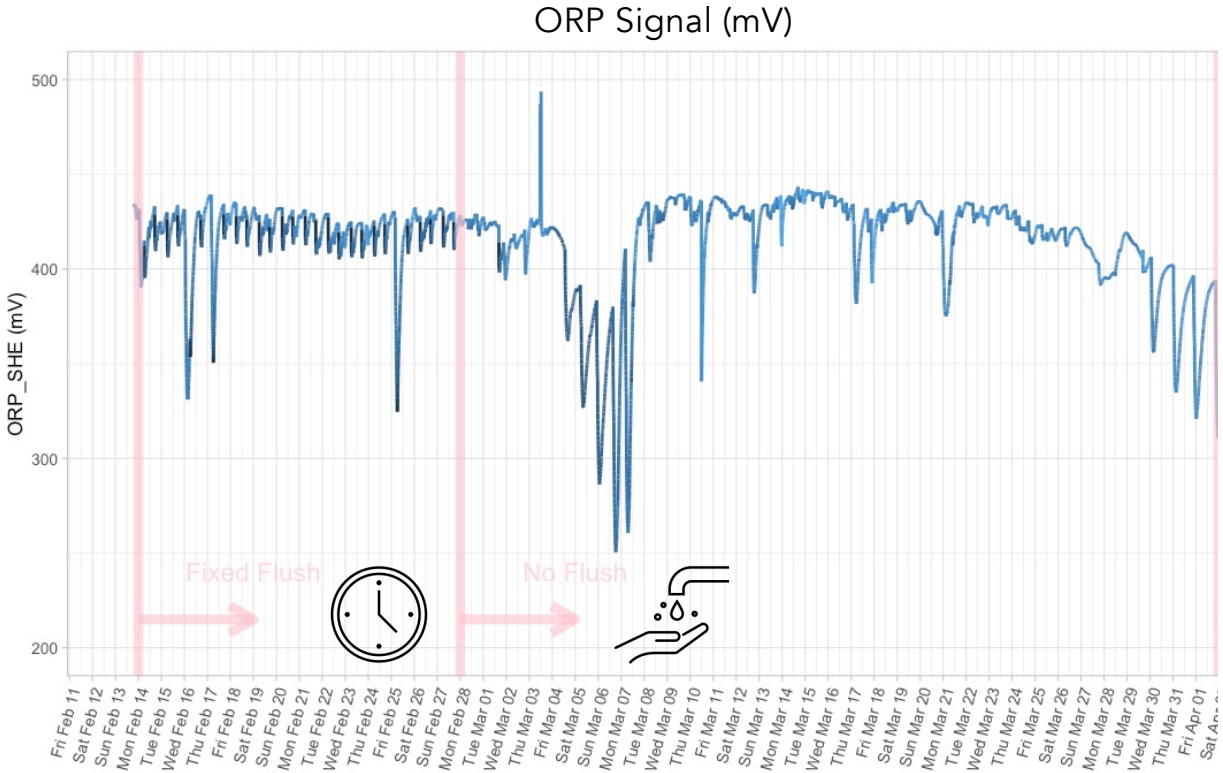
Static fixed-volume

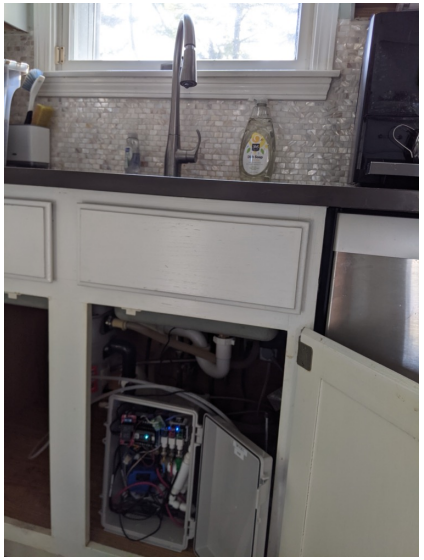
Adaptive (smart flushing)



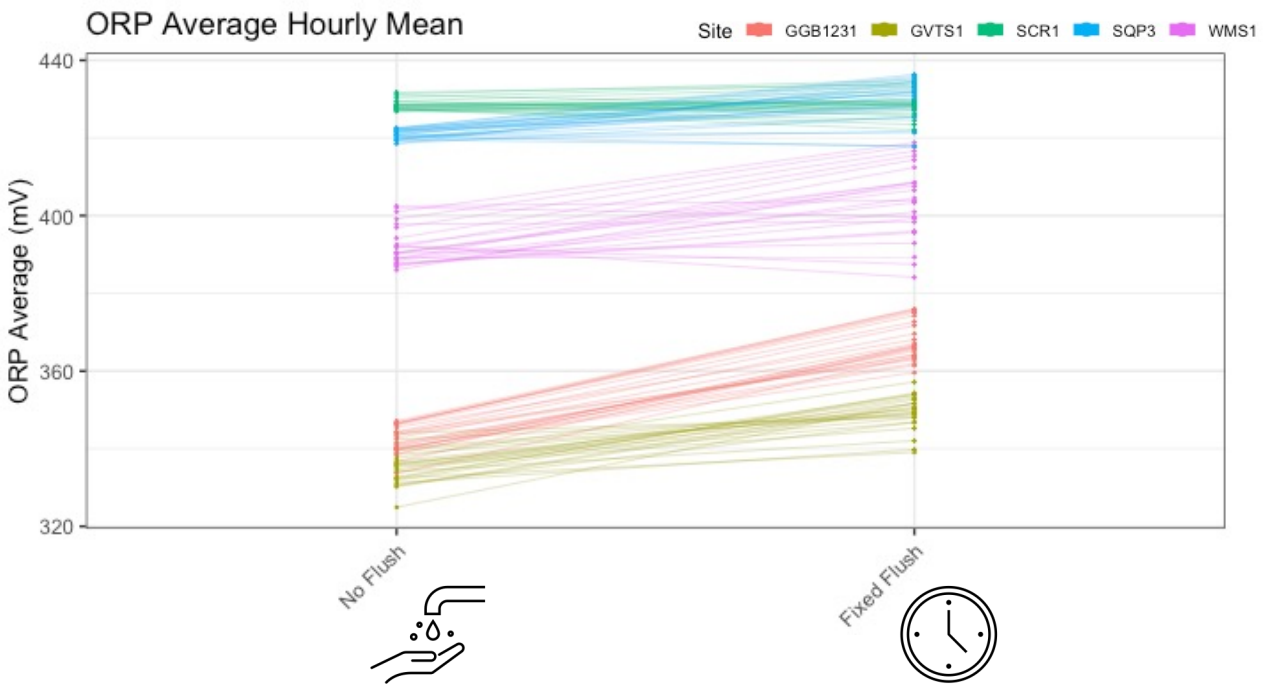


Fixed flushing resulted in a less variable ORP signal compared to no flush.

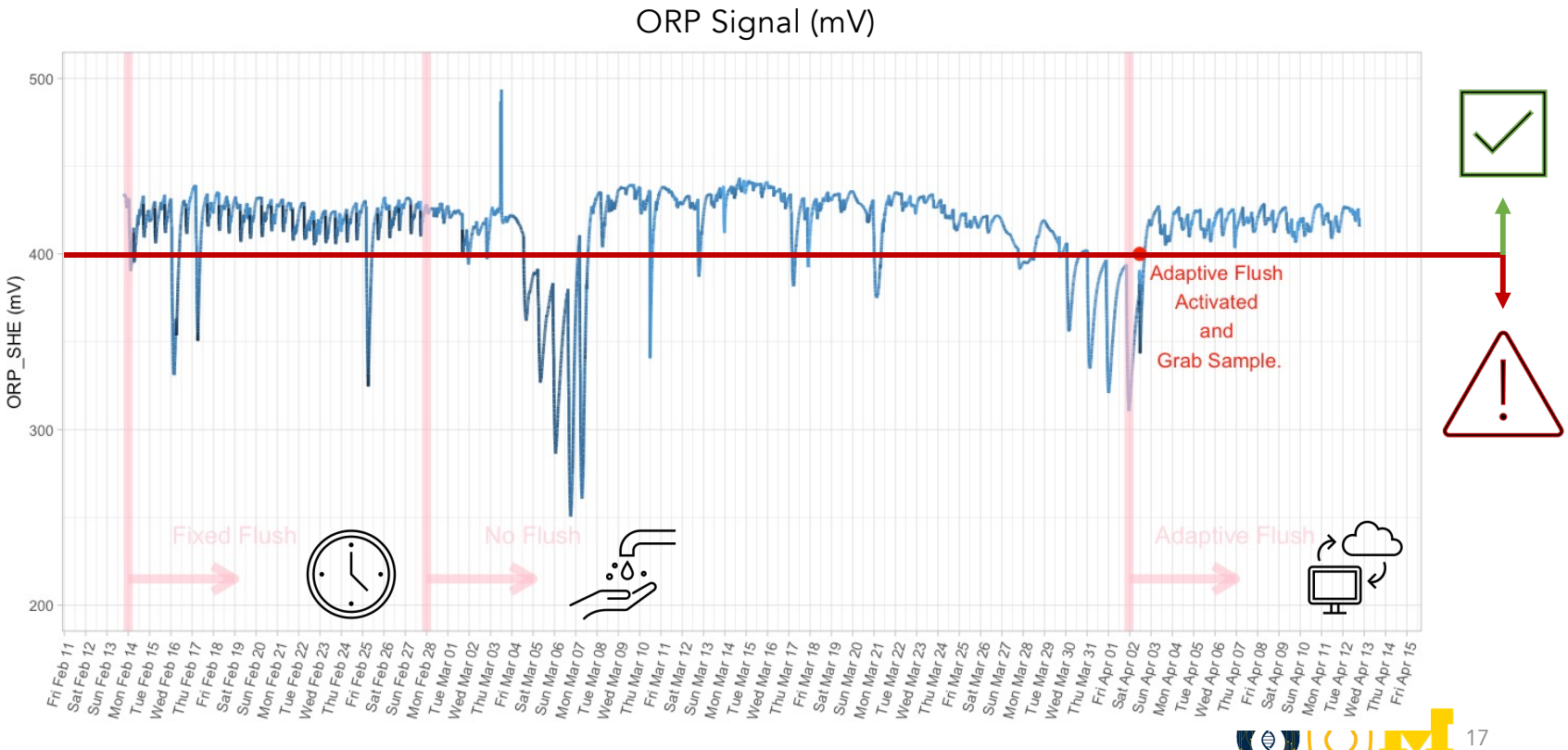




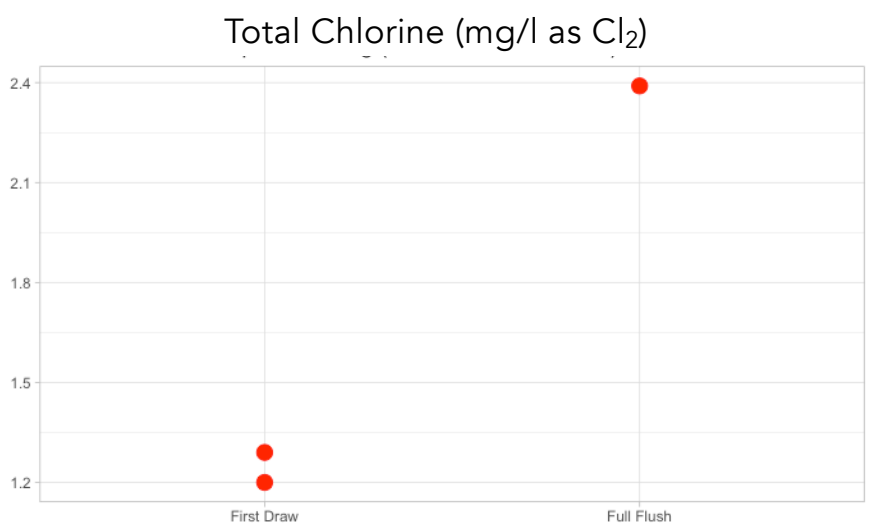
Fixed flush always resulted in higher ORP averages at the tap. Water quality improved.



Adaptive flush was programmed to flush when an ORP threshold was crossed

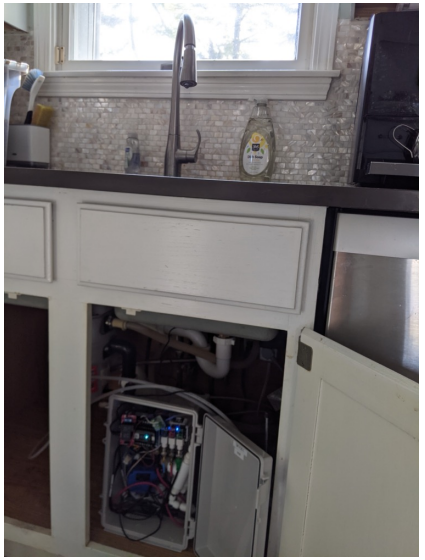


Total chlorine concentrations from grab samples confirm there is a restitution of chlorine after flushing.

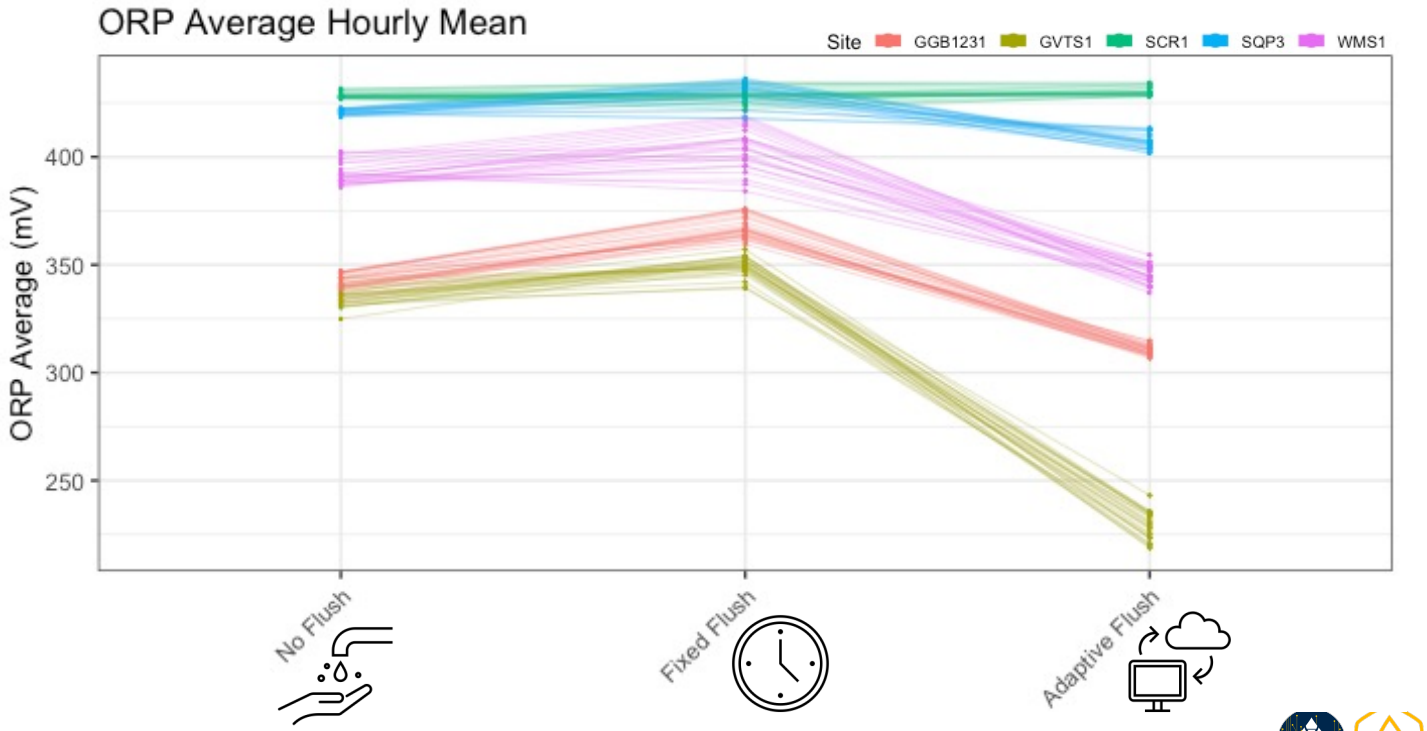


ORP < 400 mV

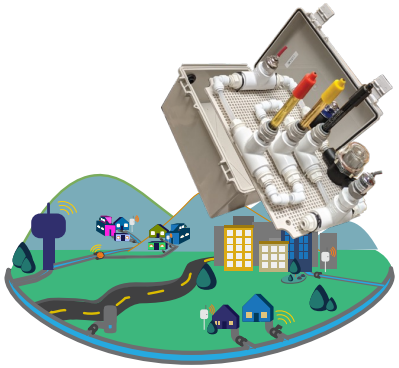
ORP > 400 mV

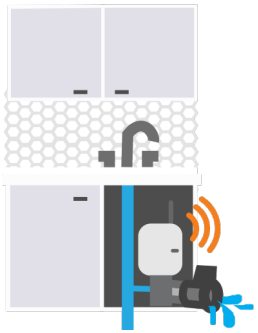


Adaptive flush resulted in lower ORP averages due to excessive flushing preventing the probes from reaching equilibrium.



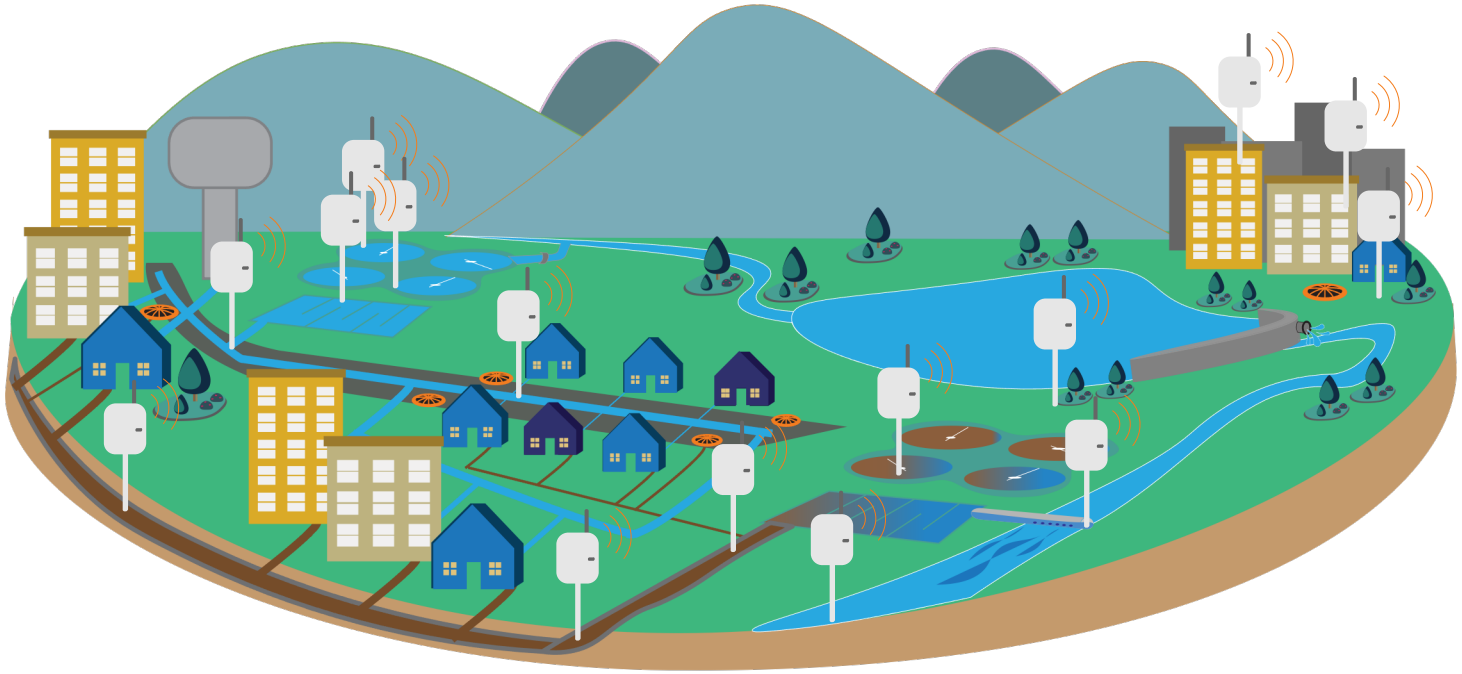
Conclusions



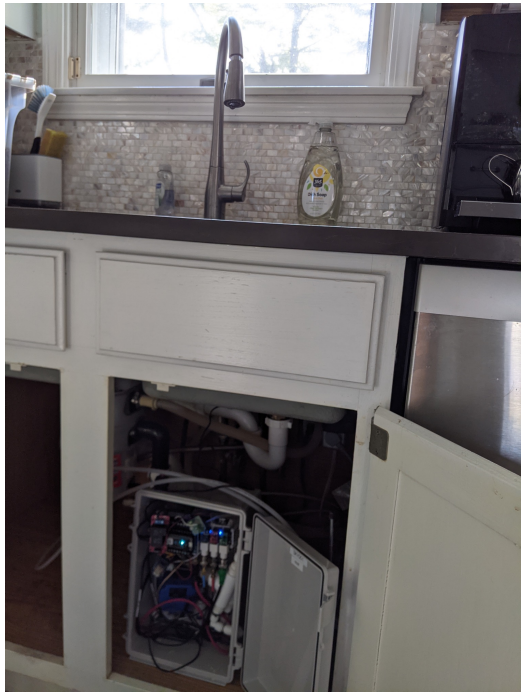


- Monitoring:
  - ORP detects different disinfecting species in drinking water
  - Real-time sensing provides insights to utilities and consumers on the system's performance (different water quality, intermittency)
  - Building plumbing water quality dynamics.
- Control:
  - ORP detects changes in concentrations, therefore we can automate and rationalize flushing in taps.
  - In need of operational development to use ORP probes within their capabilities

A Connected Urban Water Cycle



Drinking water sensing has come a long way, applications and implications are endless!



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CIVIL & ENVIRONMENTAL ENGINEERING
UNIVERSITY OF MICHIGAN

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Wigginton Group

Kerkez Group