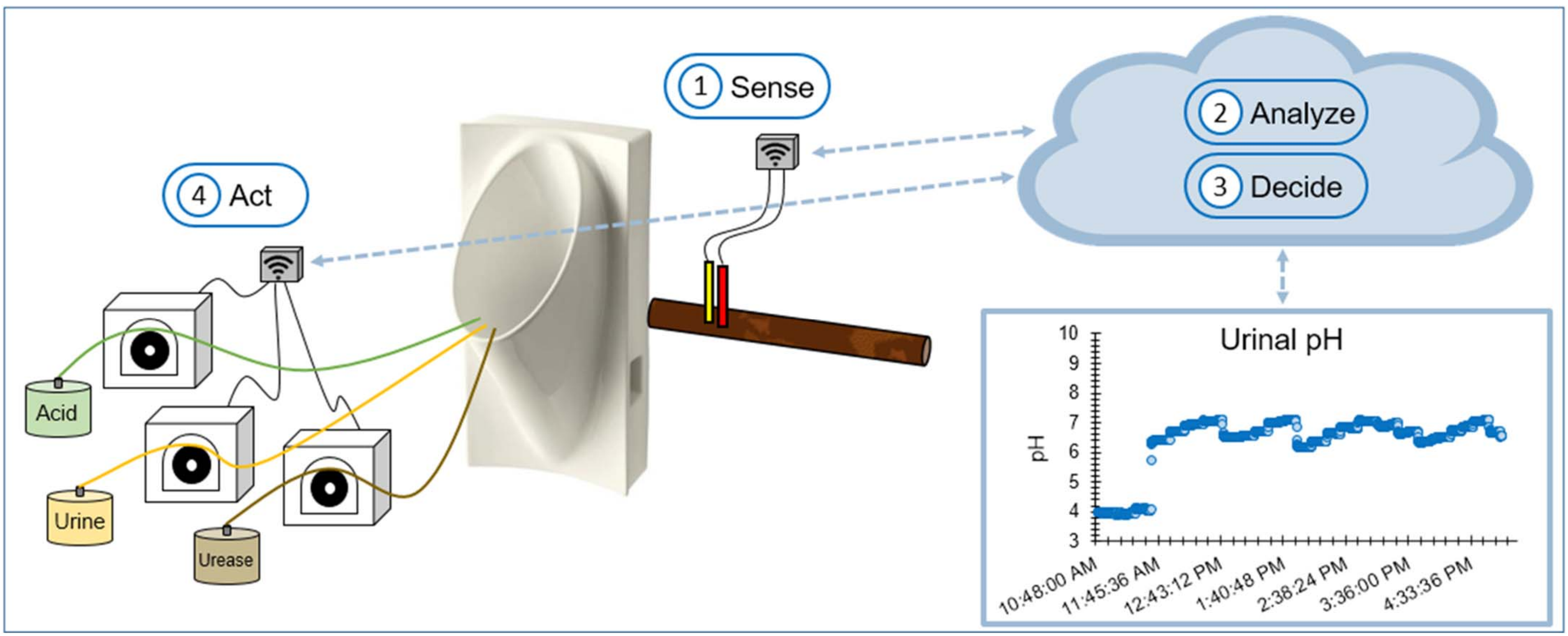
Sensor and Actuator System Transform Nonwater Urinal Into "Smart" Urinal

Treavor Boyer (thboyer@asu.edu) and Daniella Saetta

May 11, 2022



Acknowledgements

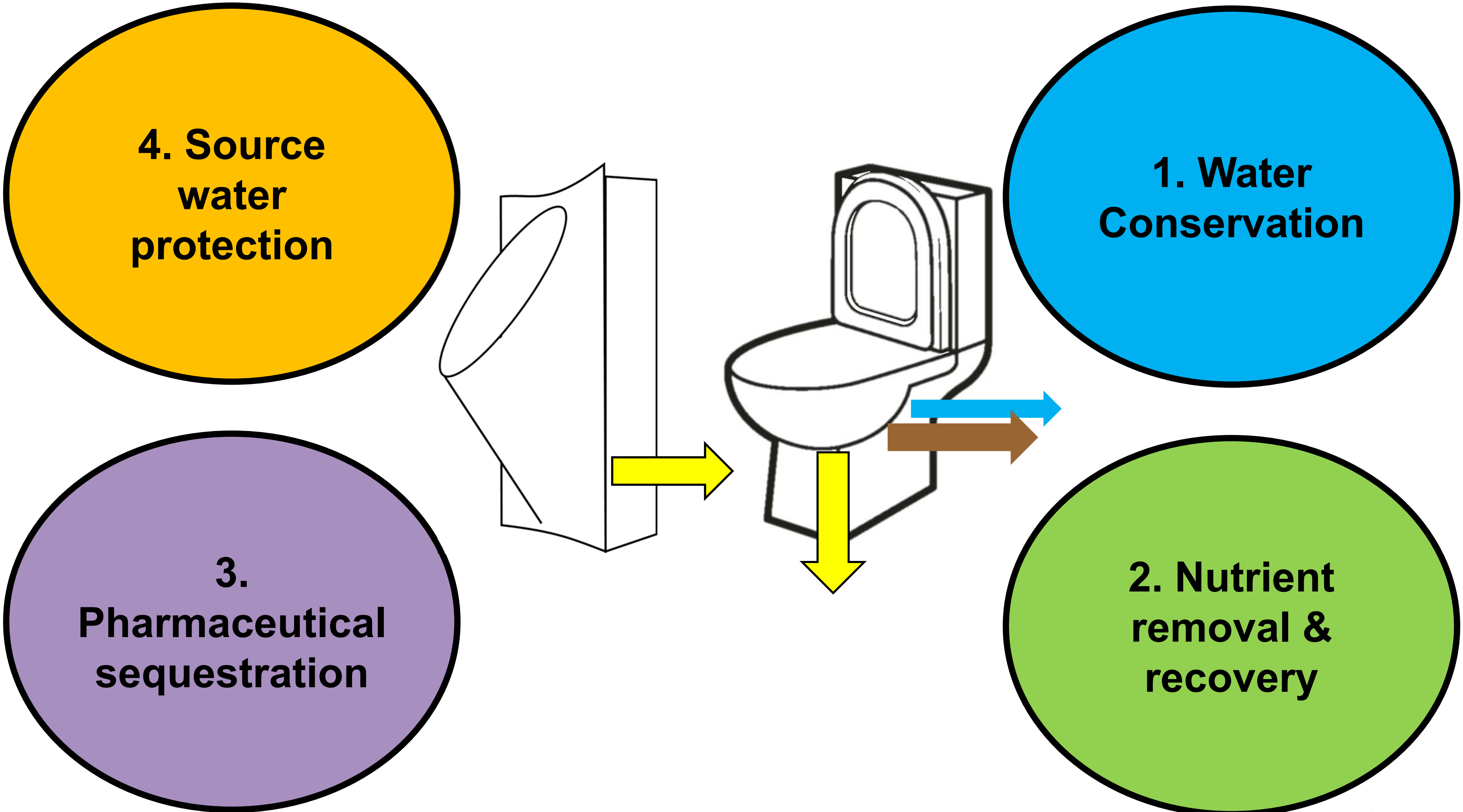
CAREER: Sustainable Urine Processes through integration of Education and Research (SUPER)

EPA Center for Reinventing Aging Infrastructure for Nutrient Management (RAINmgt)

Prevention of Pharmaceutical Water Pollution by Urine Source Separation and Treatment

Urine Source Separation and Treatment: Nutrient Recovery using Low-Cost Materials

Opportunities for urine diversion



How do we achieve radical change?

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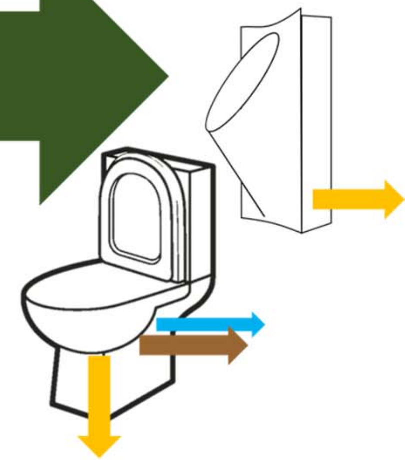


In incremental steps

Laboratory research

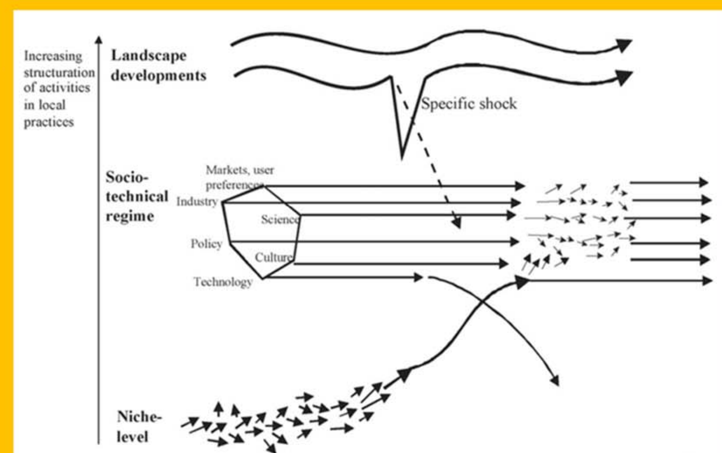
Community-scale urine collection

Research building implementation

Nonwater urinal implementation

Multiple CI building implementation

City-wide implementation



Geels and Schot, 2007

Our progress on urine diversion

1 Urine collection

Environmental Science & Technology — Article — pubs.acs.org/est

Mimicking and Inhibiting Urea Hydrolysis in Nonwater Urinals

Daniella Saetta[*,†,‡] and Treavor H. Boyer[‡]

Environmental Science & Technology — Article — Cite This: Environ. Sci. Technol. 2019, 53, 3187−3197 — pubs.acs.org/est

Real-Time Monitoring and Control of Urea Hydrolysis in Cyber-Enabled Nonwater Urinal System

Daniella Saetta,[*,†] Arsh Padda,[‡] Xiushuang Li,[‡] Carlos Leyva,[§] Pitu B. Mirchandani,[‡] Dragan Boscovic,[‡,||] and Treavor H. Boyer[†]

IEEE Access

Water and Wastewater Building CPS: Creation of Cyber-Physical Wastewater Collection System Centered on Urine Diversion

DANIELLA SAETTA[1], (Member, IEEE), ARSH PADDA[2], XIUSHUANG LI[2], CARLOS LEYVA[3], PITU B. MIRCHANDANI[2], (Life Fellow, IEEE), DRAGAN BOSCOVIC[2,4], AND TREAVOR H. BOYER[1], (Member, IEEE)

2 Pharmaceutical Removal

Available online at www.sciencedirect.com — ScienceDirect — journal homepage: www.elsevier.com/locate/watres — Water Research

Ion-exchange selectivity of diclofenac, ibuprofen, ketoprofen, and naproxen in ureolyzed human urine

Kelly A. Landry[a,*], Peizhe Sun[b], Ching-Hua Huang[b], Treavor H. Boyer[a]

Environmental Science Water Research & Technology — PAPER

Pharmaceutical removal in synthetic human urine using biochar†

Cite this: Environ. Sci.: Water Res. Technol., 2017, 3, 553

Avni Solanki[*a] and Treavor H. Boyer[b]

3 N, P, & K Recovery

Environmental Science Water Research & Technology — PAPER

Integrated, multi-process approach to total nutrient recovery from stored urine†

Cite this: DOI: 10.1039/c8ew00004b

Neha Jagtap[*ab] and Treavor H. Boyer[b]

Environmental Science Water Research & Technology — PAPER

Phosphorus recovery from urine and anaerobic digester filtrate: comparison of adsorption–precipitation with direct precipitation†

Cite this: Environ. Sci.: Water Res. Technol., 2015, 1, 481

Jeremy A. O'Neal and Treavor H. Boyer[*]

Contents lists available at SciVerse ScienceDirect — Desalination — journal homepage: www.elsevier.com/locate/desal

Phosphate removal from urine using hybrid anion exchange resin

Alicia Sendrowski, Treavor H. Boyer[*]

Environmental Science Water Research & Technology — PAPER

Urea recovery from fresh human urine by forward osmosis and membrane distillation (FO–MD)†

Cite this: Environ. Sci.: Water Res. Technol., 2019, 5, 1993

Hannah Ray,[*] Francois Perreault and Treavor H. Boyer

Environmental Science & Technology — Article — pubs.acs.org/est

Ammonia Recovery from Hydrolyzed Human Urine by Forward Osmosis with Acidified Draw Solution

Hannah Ray,[*] Francois Perreault, and Treavor H. Boyer

Agricultural and Food Chemistry — Article — Cite This: J. Agric. Food Chem. 2019, 67, 50−62 — pubs.acs.org/JAFC

Human Urine as a Fertilizer in the Cultivation of Snap Beans (*Phaseolus vulgaris*) and Turnips (*Brassica rapa*)

Madelyn Pandorf,[*,†,‡] George Hochmuth,[§] and Treavor H. Boyer[†]

4 Life Cycle Impacts

Available online at www.sciencedirect.com — ScienceDirect — journal homepage: www.elsevier.com/locate/watres — Water Research

Life cycle comparison of centralized wastewater treatment and urine source separation with struvite precipitation: Focus on urine nutrient management

Stephanie K.L. Ishii[*], Treavor H. Boyer

Contents lists available at ScienceDirect — Water Research — journal homepage: www.elsevier.com/locate/watres

Life cycle assessment and costing of urine source separation: Focus on nonsteroidal anti-inflammatory drug removal

Kelly A. Landry[a,*], Treavor H. Boyer[b]

Environmental Science & Technology — Article — pubs.acs.org/est

Fixed Bed Modeling of Nonsteroidal Anti-Inflammatory Drug Removal by Ion-Exchange in Synthetic Urine: Mass Removal or Toxicity Reduction?

Kelly A. Landry[*,†] and Treavor H. Boyer[*,‡]

Contents lists available at ScienceDirect — Journal of Environmental Chemical Engineering — journal homepage: www.elsevier.com/locate/jece

Urine collection in a multi-story building and opportunities for onsite recovery of nutrients and non-potable water

Neha S. Jagtap[a,b,*], Treavor H. Boyer[a]

5 User Opinions

Contents lists available at ScienceDirect — Water Research — journal homepage: www.elsevier.com/locate/watres

Student support and perceptions of urine source separation in a university community

Stephanie K.L. Ishii[*,*], Treavor H. Boyer[*]

Department of Environmental Engineering Sciences, Engineering School of Sustainable Infrastructure and Environment (ESSIE), University of Florida, PO Box 116450, Gainesville, FL 32611-6450, USA

Objectives for today

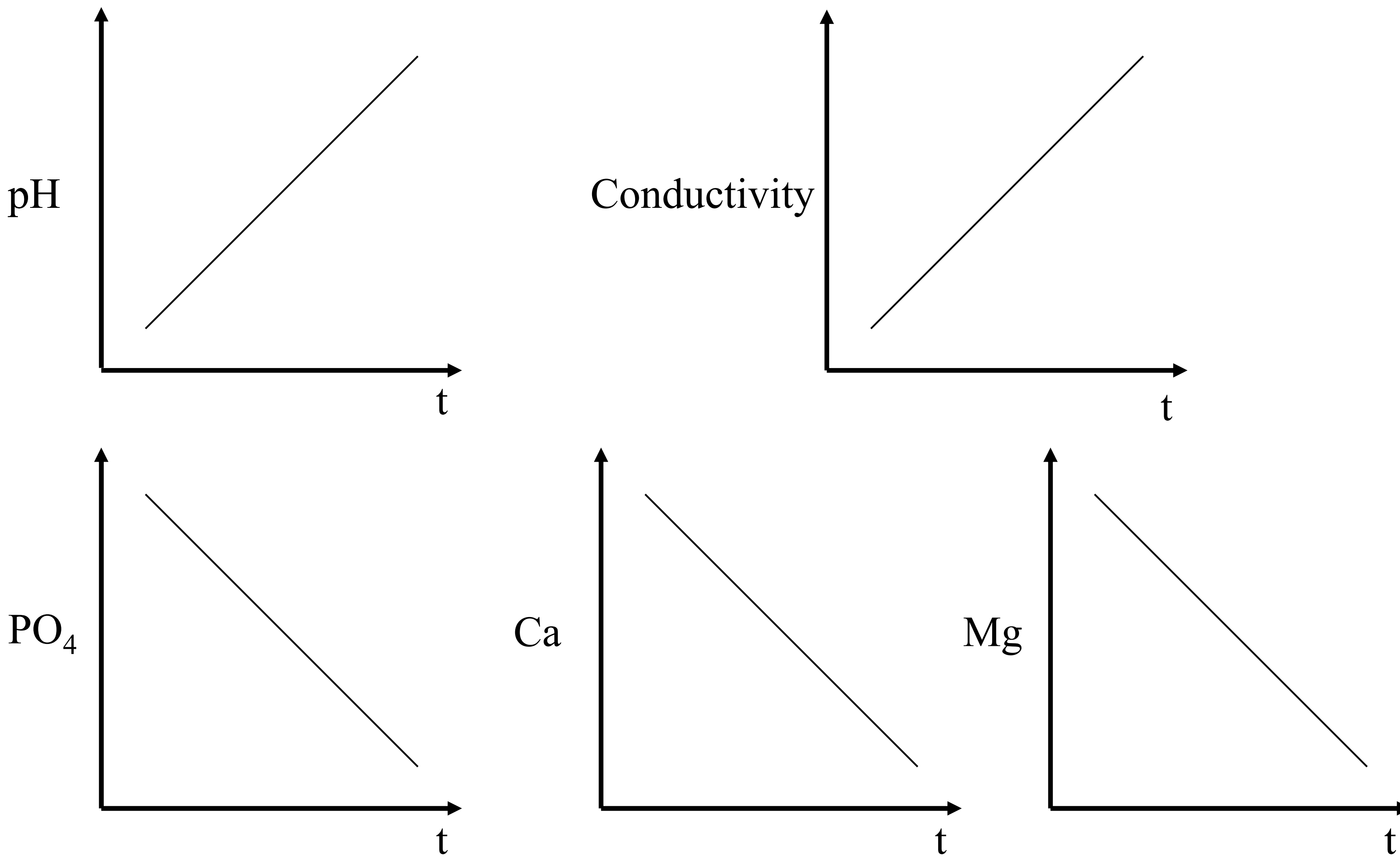
1. Describe the process of urea hydrolysis, its impact on nonwater urinals and urine collection, and its inhibition by chemical addition.

2. Describe the use of sensors and actuators to monitor and manipulate urine chemistry.

3. Highlight results from innovative urinal testbeds that integrate sensors and actuators for urine collection.

Urea hydrolysis and precipitation

$$NH_2(CO)NH_2 + 3H_2O \xrightarrow{urease} 2NH_4^+ + HCO_3^- + OH^-$$

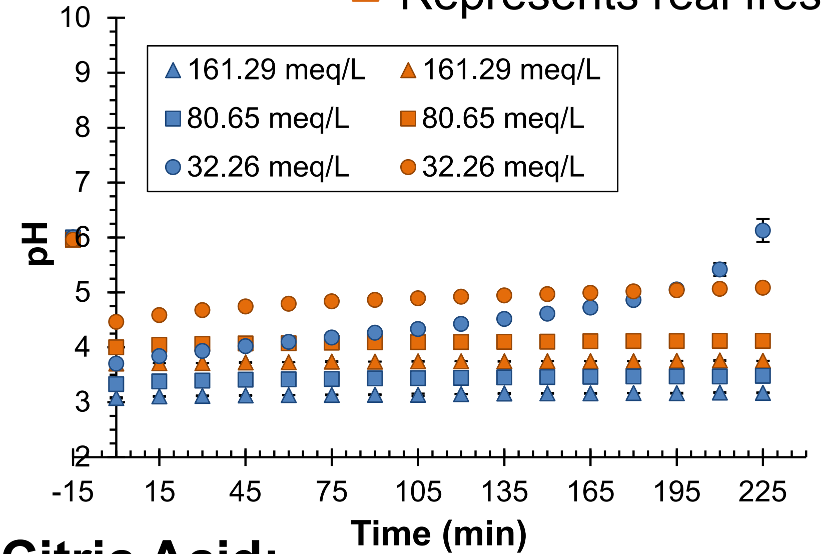


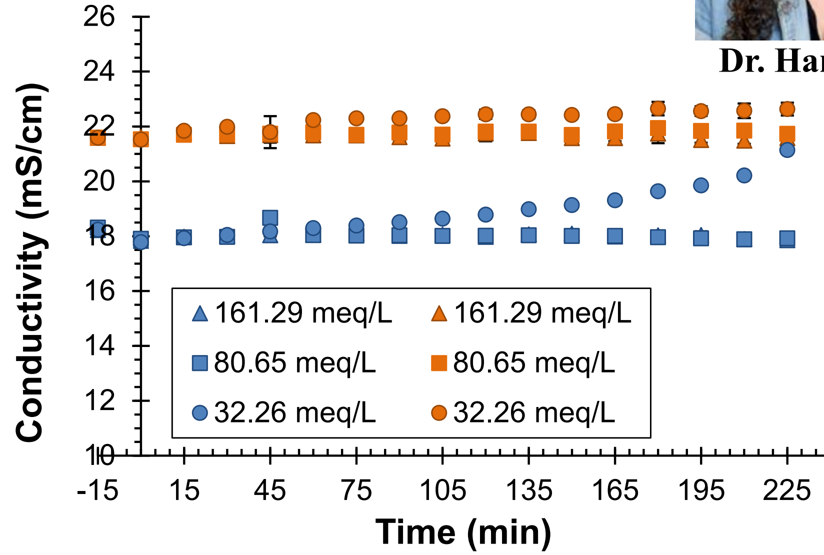
Inhibiting urea hydrolysis


Dr. Hannah Ray

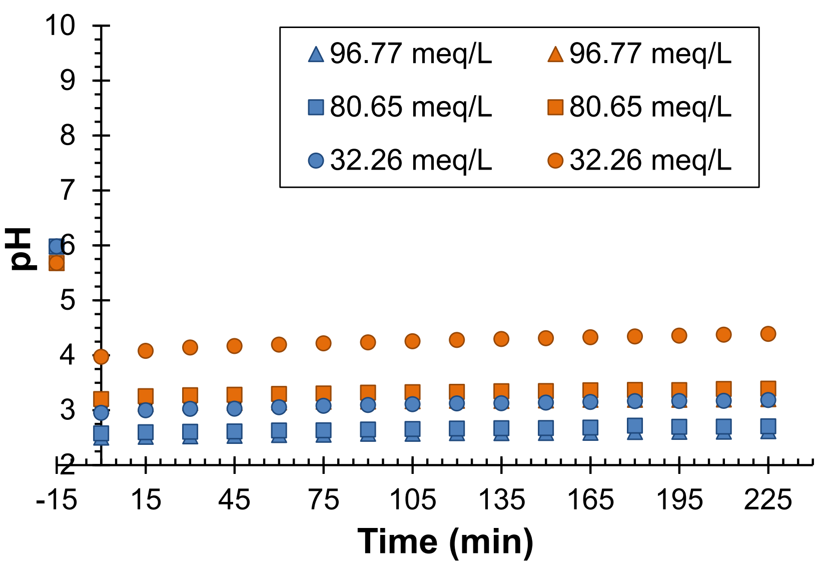
Acetic Acid:

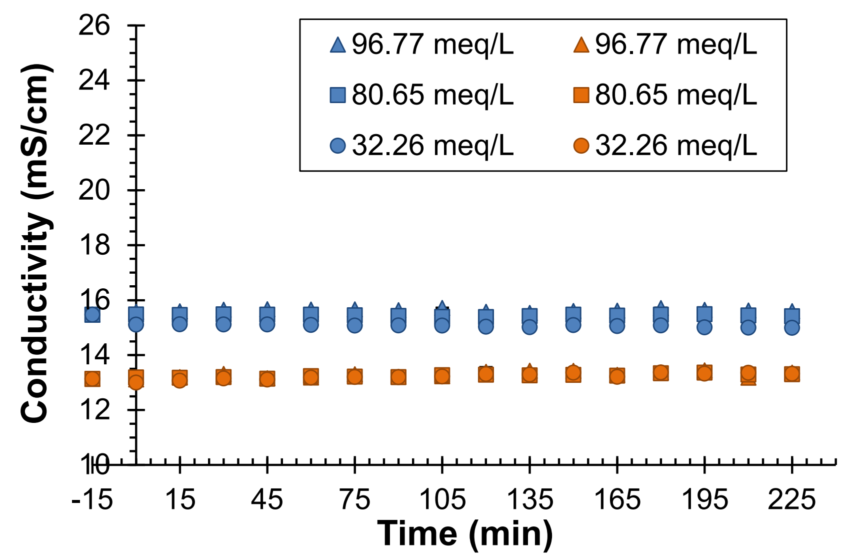
■ Represent synthetic fresh urine
■ Represents real fresh urine





Citric Acid:

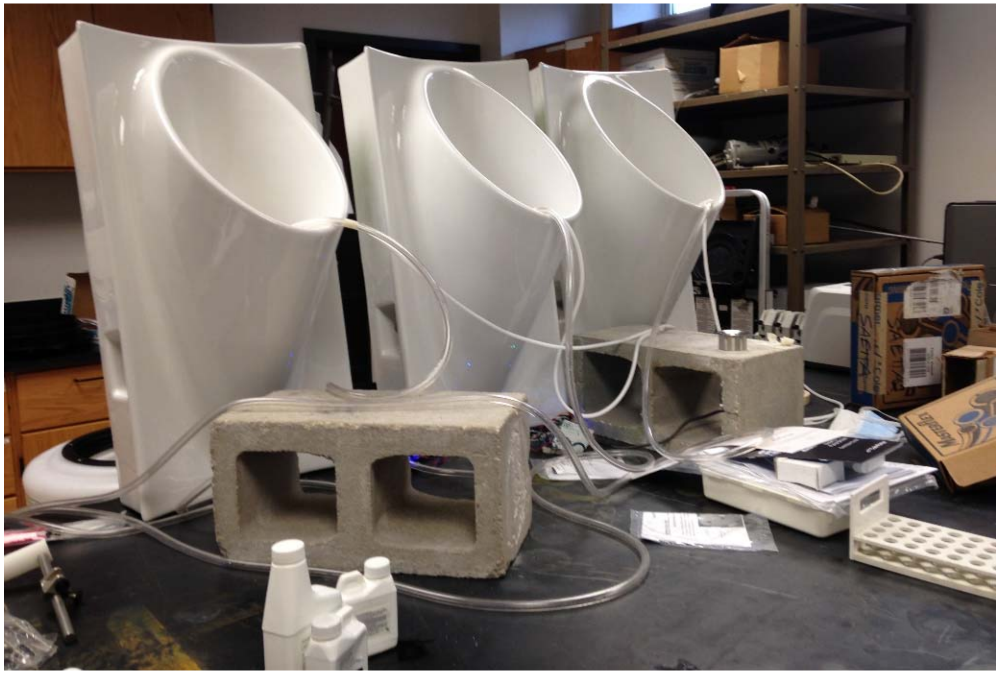


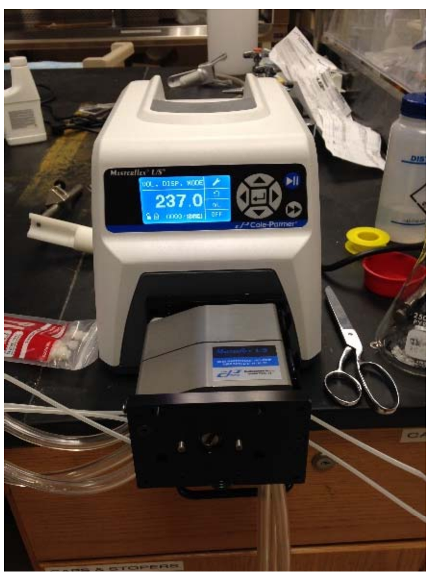


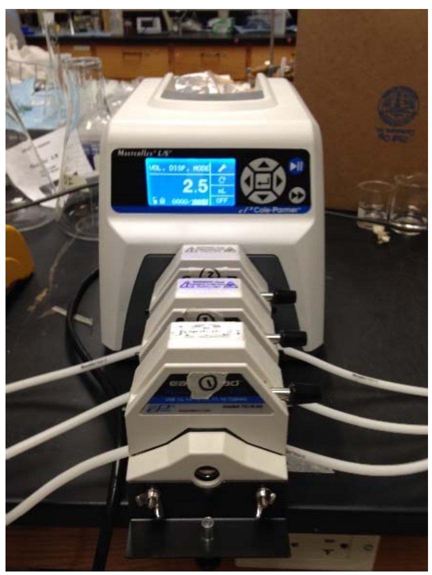
Ray, Saetta and Boyer, 2018. *Environ. Sci.: Water Res. Technol.*

Urine diversion testbed @ UF

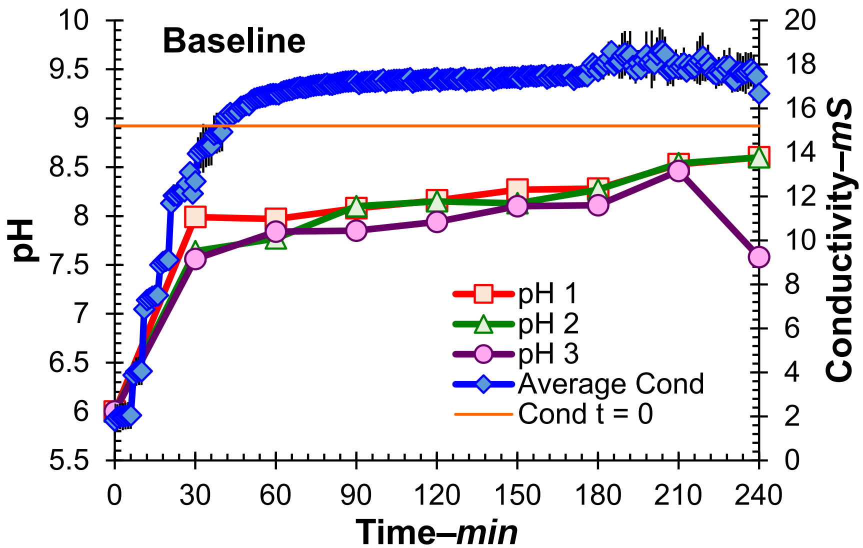
Dr. Daniella Saetta

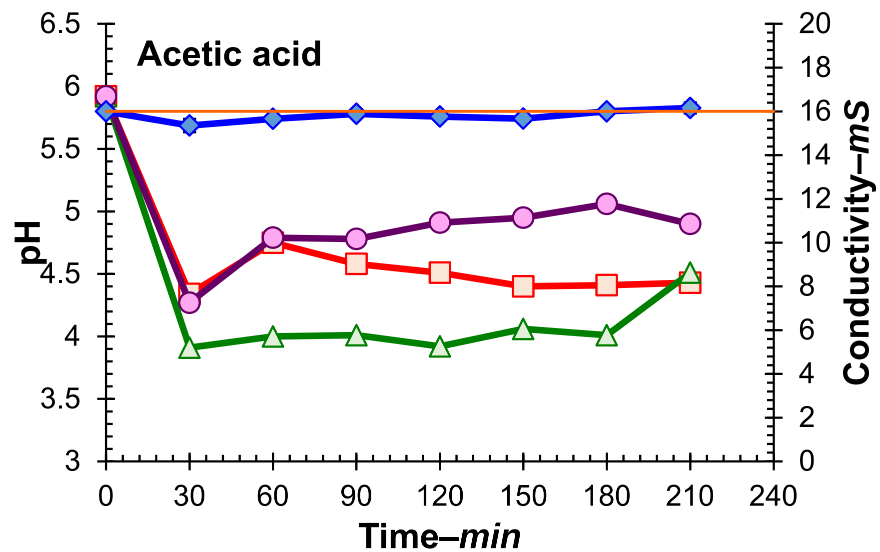






Mimicking and inhibiting urea hydrolysis in nonwater urinals

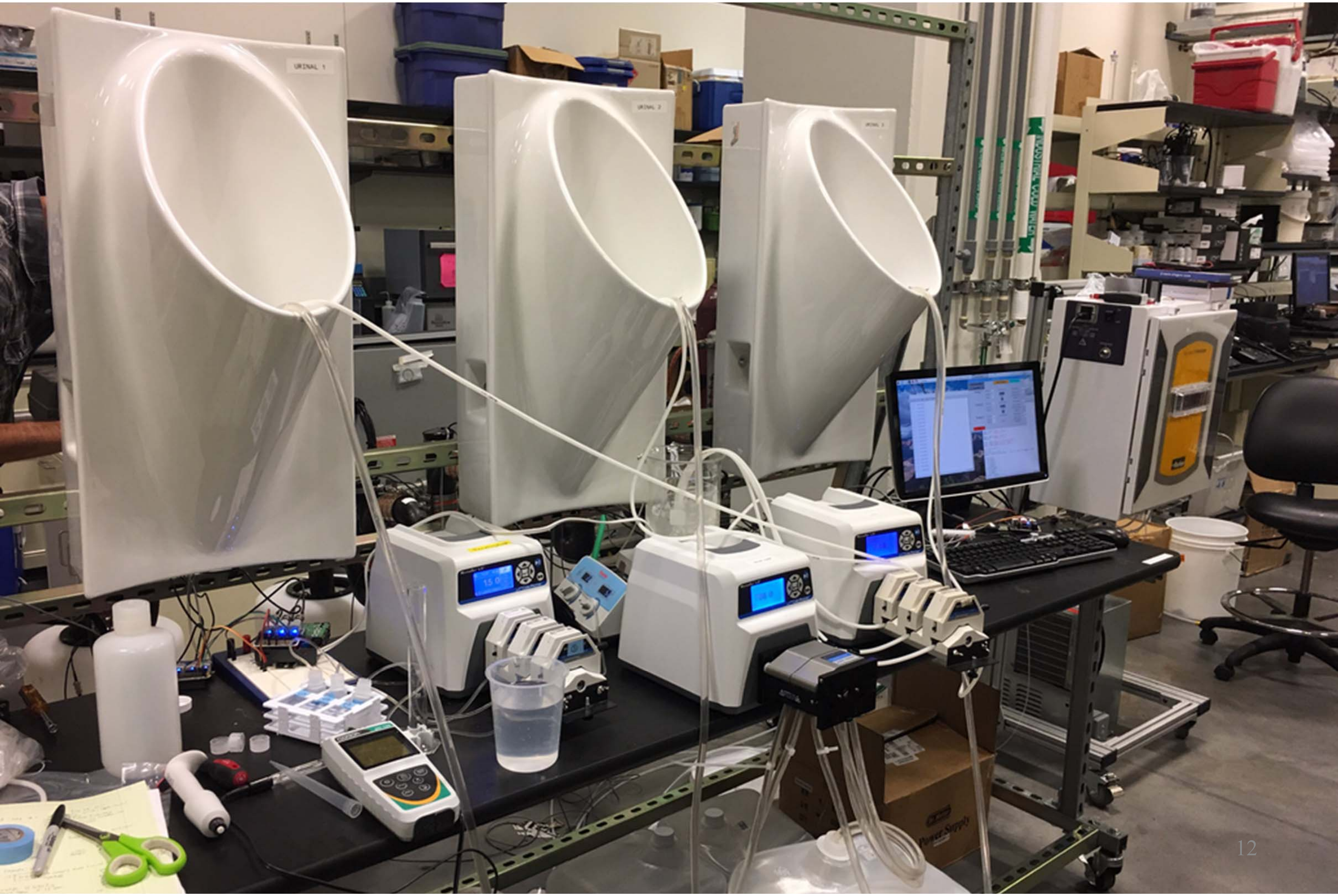




Test	Percent PO_4 recovered
Baseline	31
Acetic Acid Addition	74

Saetta and Boyer, 2017. *Environ. Sci. Technol.*

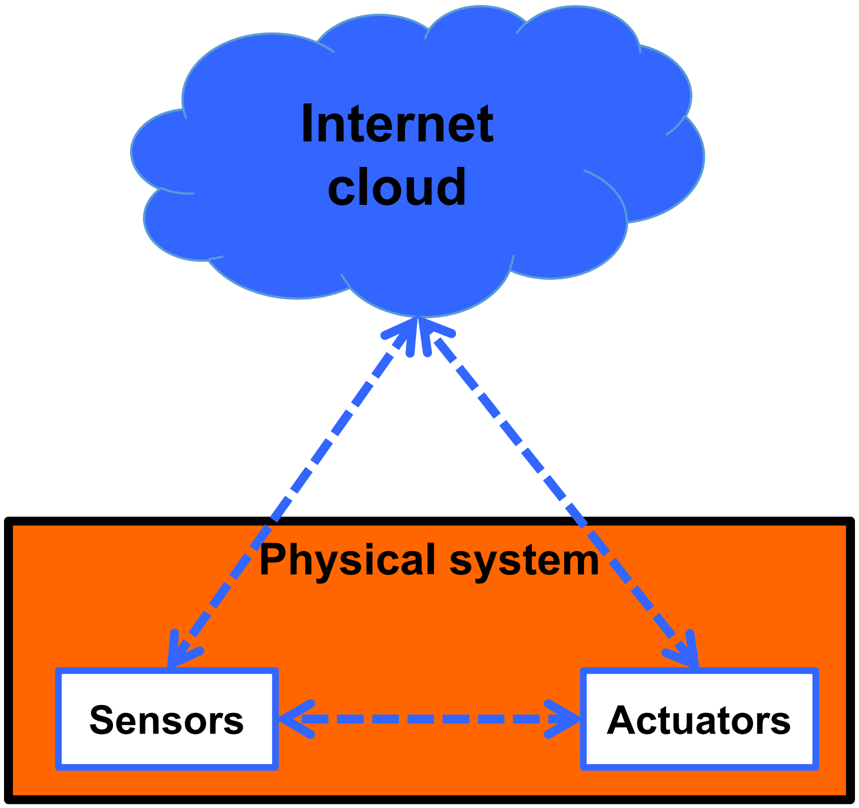
Urine diversion testbed @ ASU



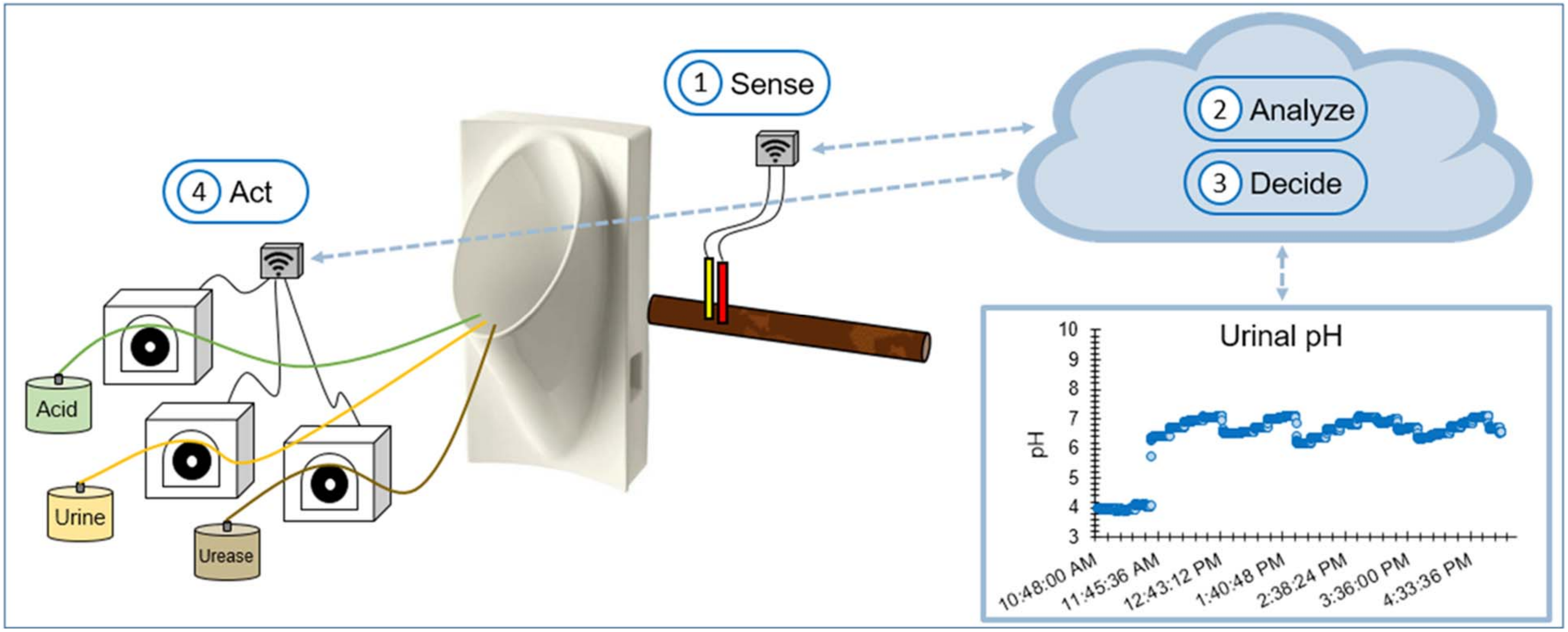

TAMCO
TAMCO

Cyber-physical system (CPS)

- A CPS represents the integration of physical and embedded systems with communication and information technology systems
- Applications in energy, security, and transportation systems
- Limited previous research on CPS applications to water or wastewater systems

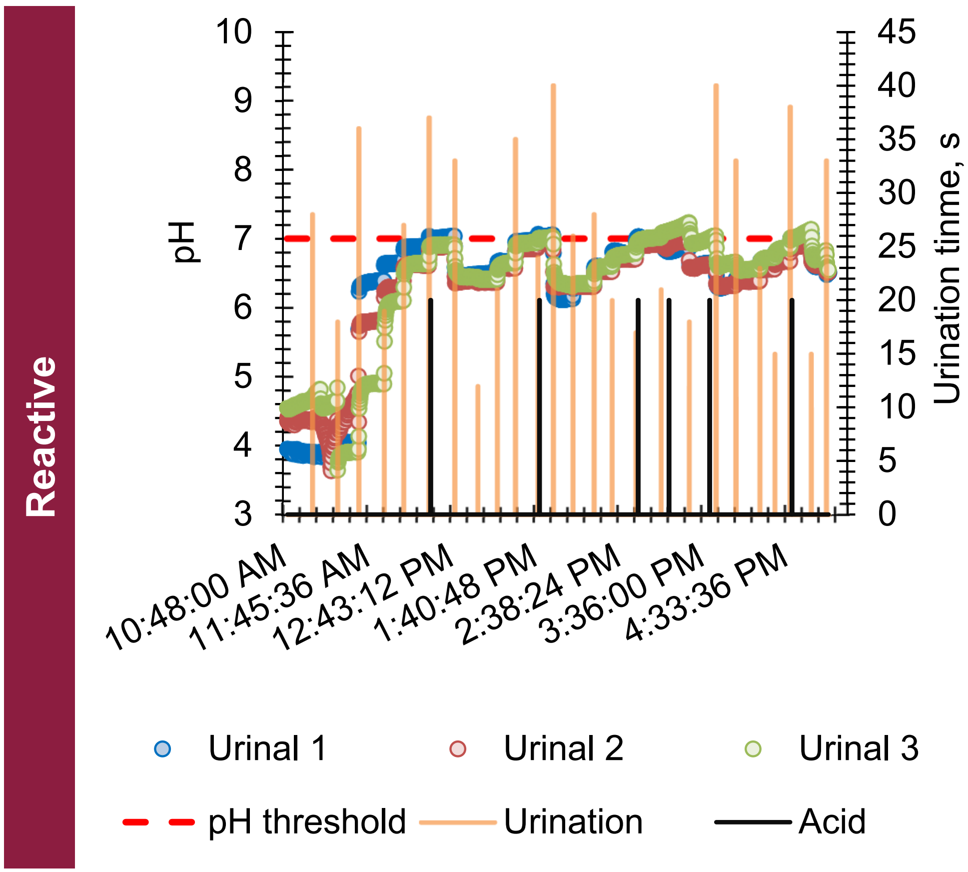


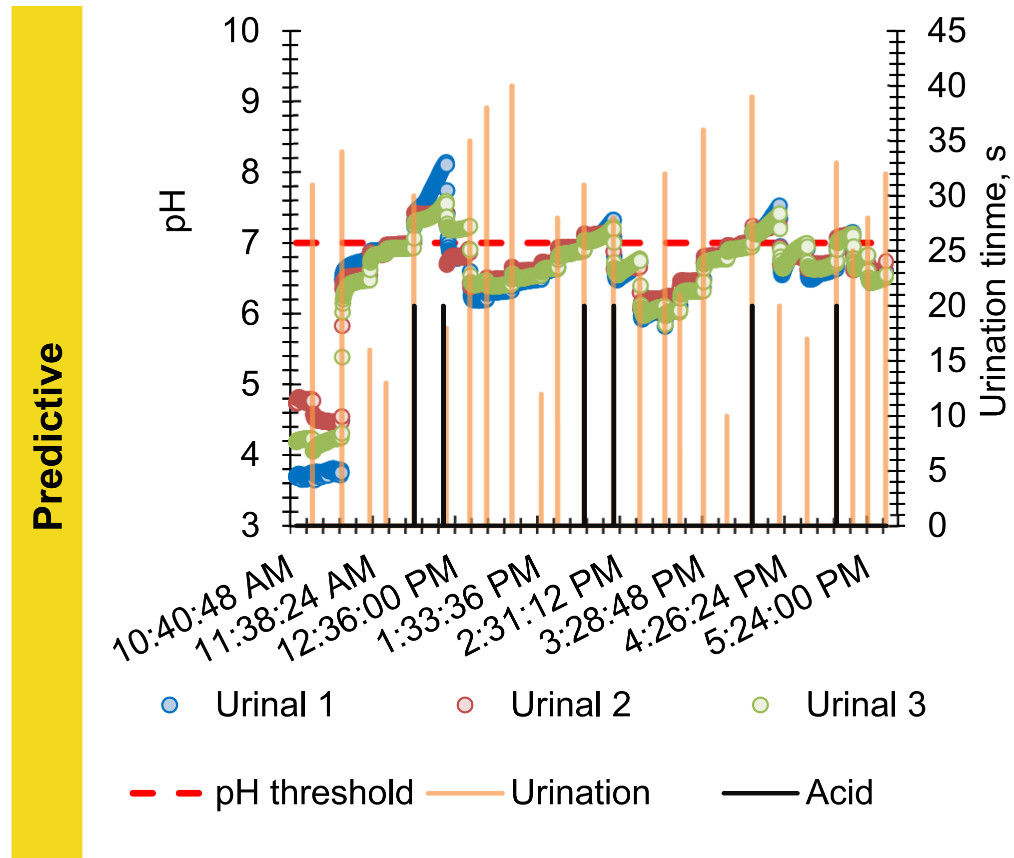
Urine diversion CPS



Compare control logic: pH

- Low urination frequency: 10–20 min
- Reactive control: pH threshold
- Predictive control: Regression model

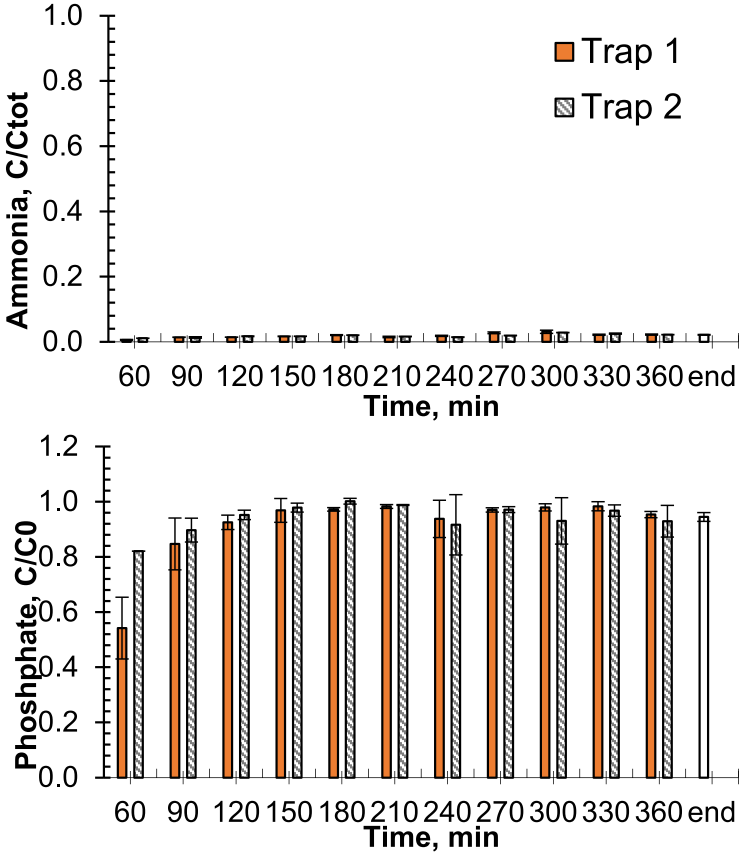




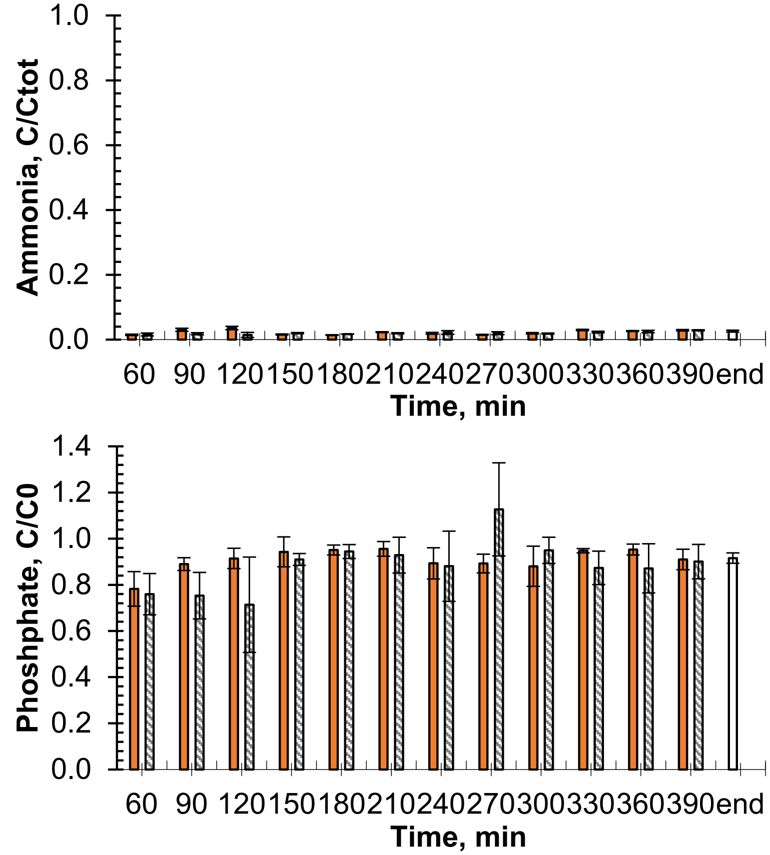
Saetta et al., 2019. *IEEE Access*; Saetta et al., 2019. *Environ. Sci. Technol.*

Compare control logic: Ammonia & phosphate

Reactive



Predictive

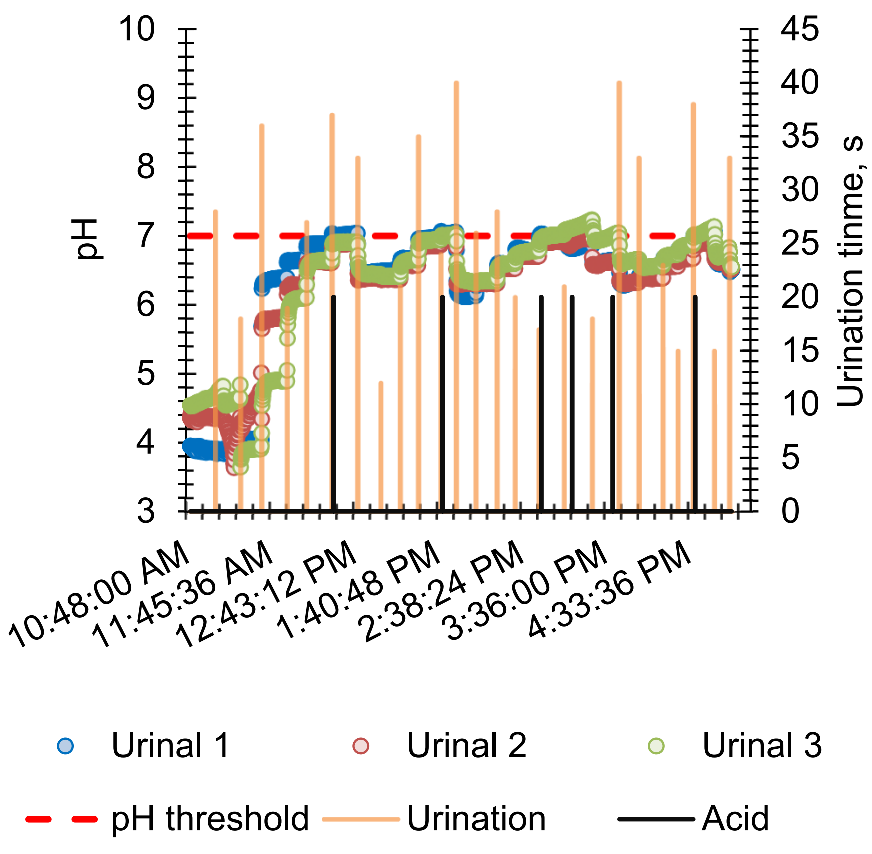


Saetta et al., 2019. *IEEE Access*; Saetta et al., 2019. *Environ. Sci. Technol.*

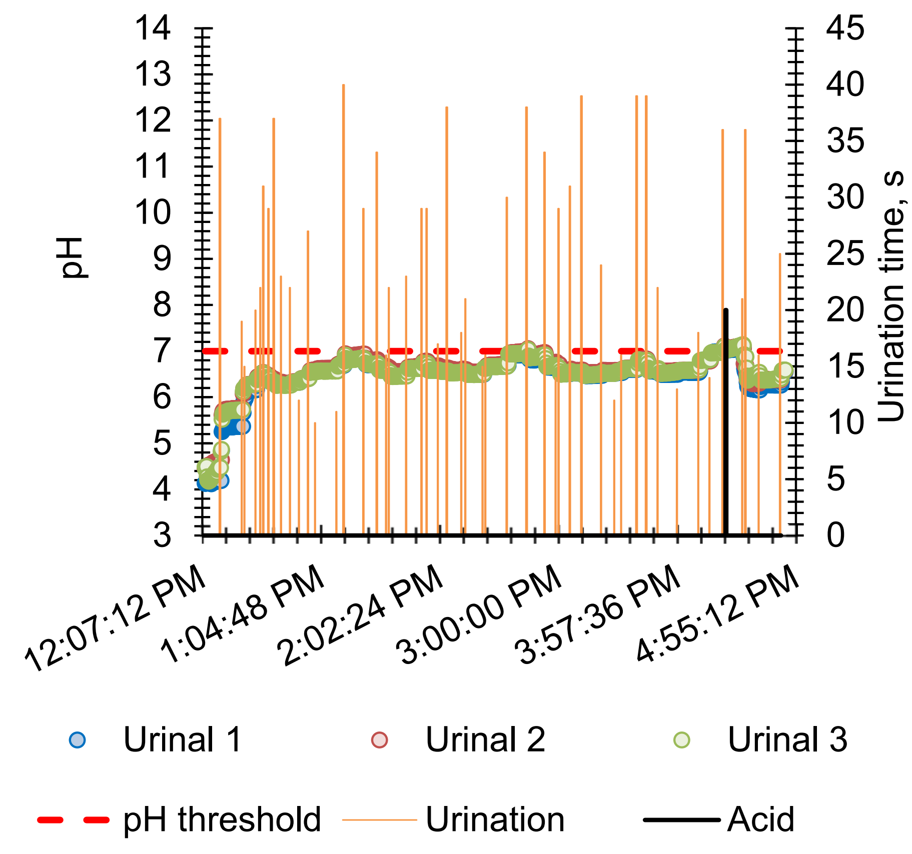
Compare urination frequency: pH

- Low urination frequency: 10–20 min
- High urination frequency: 1–10 min
- Predictive control: Regression model

Low frequency

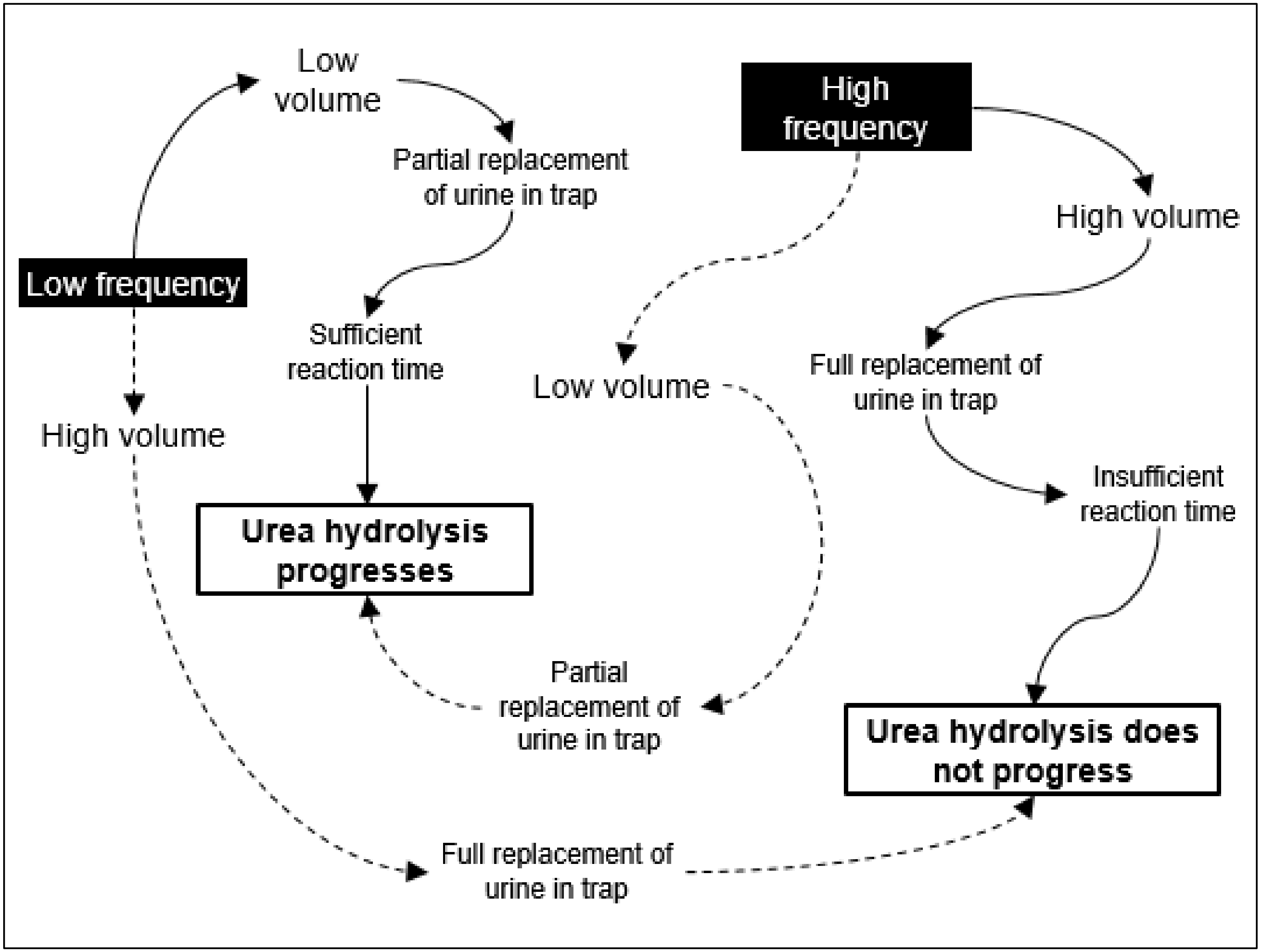


High frequency



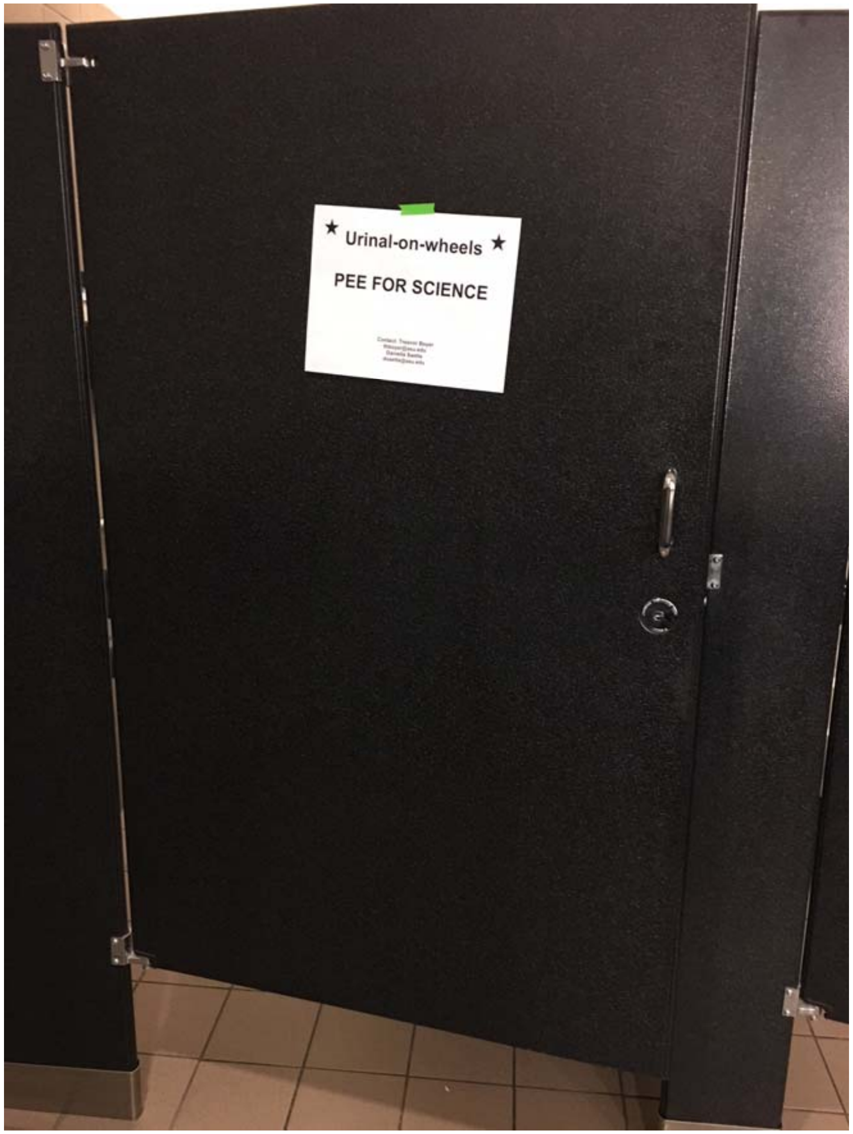
Saetta et al., 2019. *IEEE Access*; Saetta et al., 2019. *Environ. Sci. Technol.*

Conceptual model for urea hydrolysis

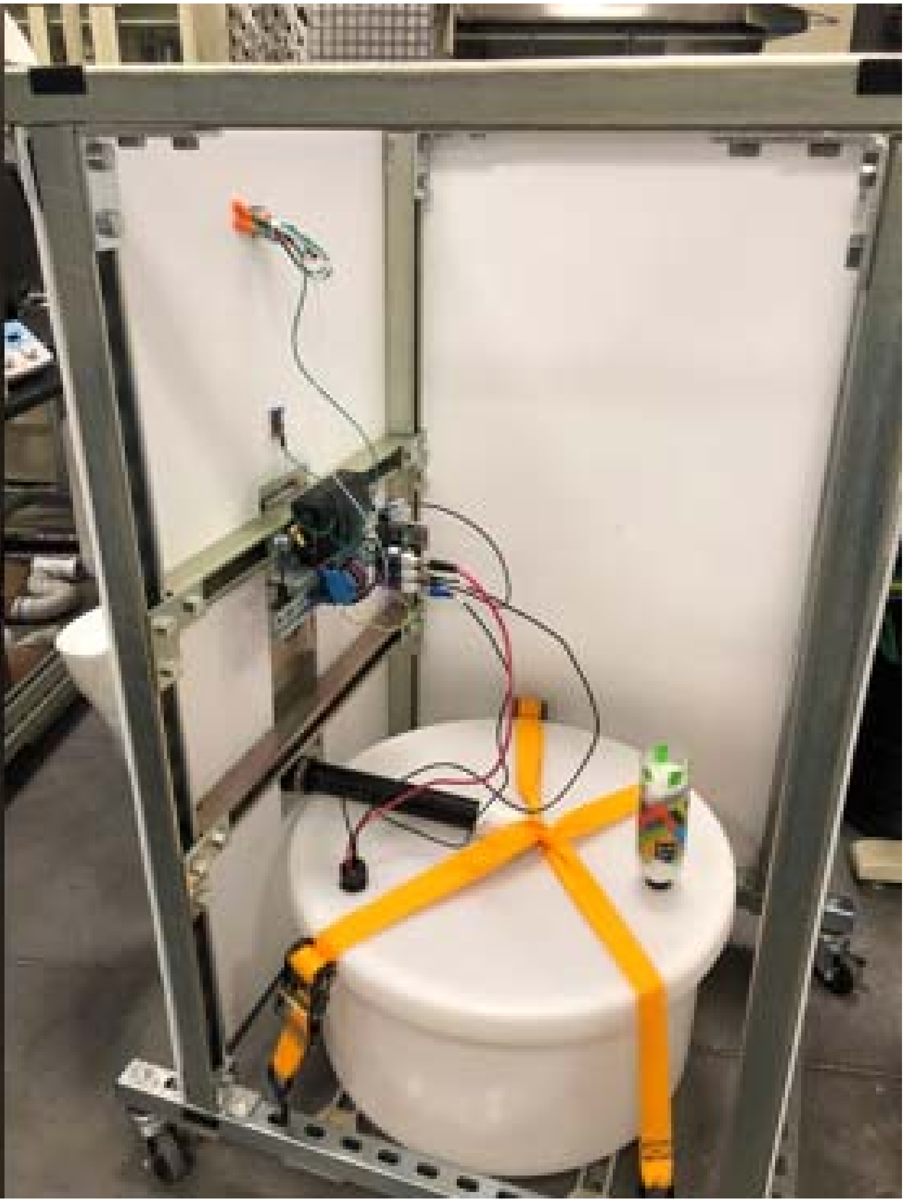


Saetta et al., 2019. *IEEE Access*; Saetta et al., 2019. *Environ. Sci. Technol.*

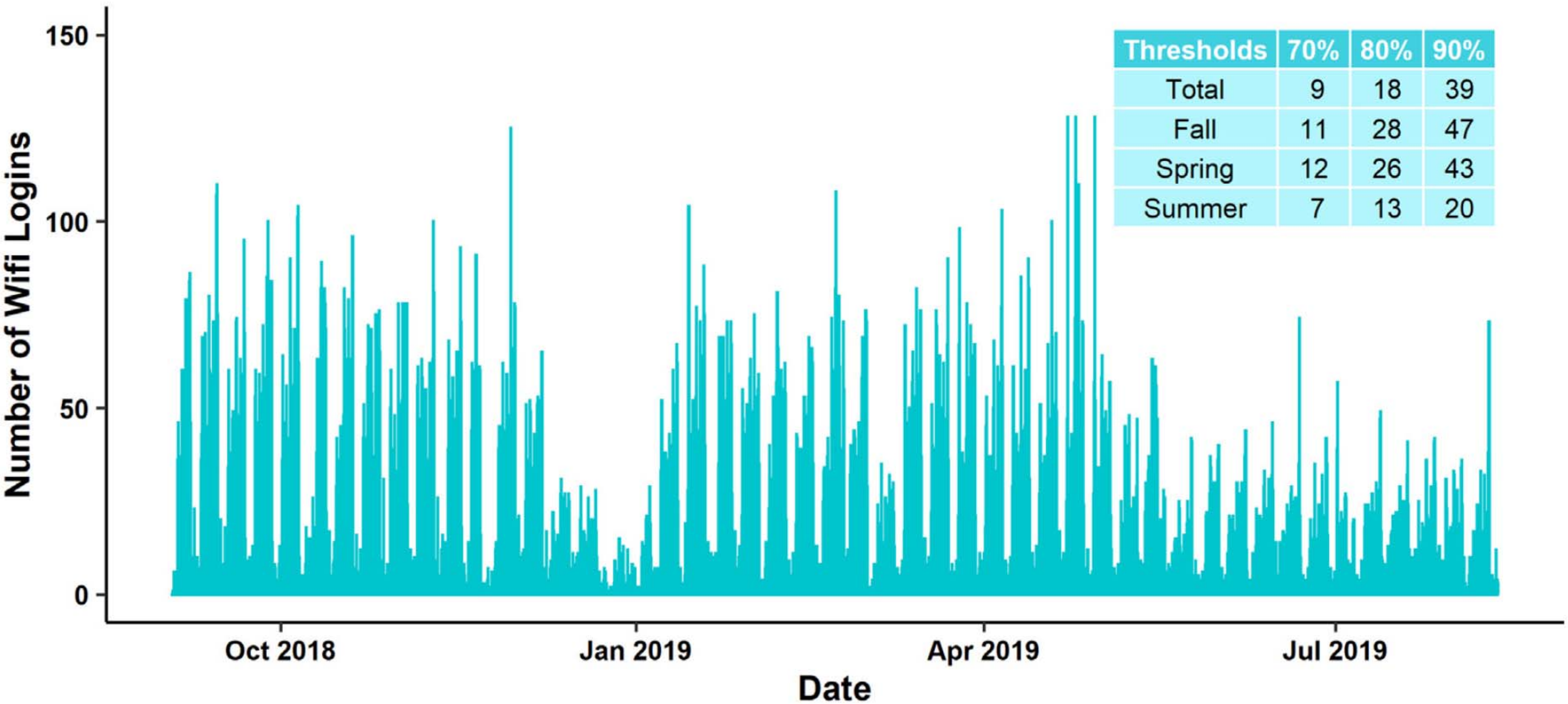
From laboratory to restroom testbed



Urinal-on-wheels



Control of urea hydrolysis considering building occupancy patterns



Thresholds	70%	80%	90%
Total	9	18	39
Fall	11	28	47
Spring	12	26	43
Summer	7	13	20

Saetta et al., 2020. *Sci. Total Environ.*

Impact of acetic acid on urine collection

Runs 1 & 2

No acid addition

Runs 3 & 4

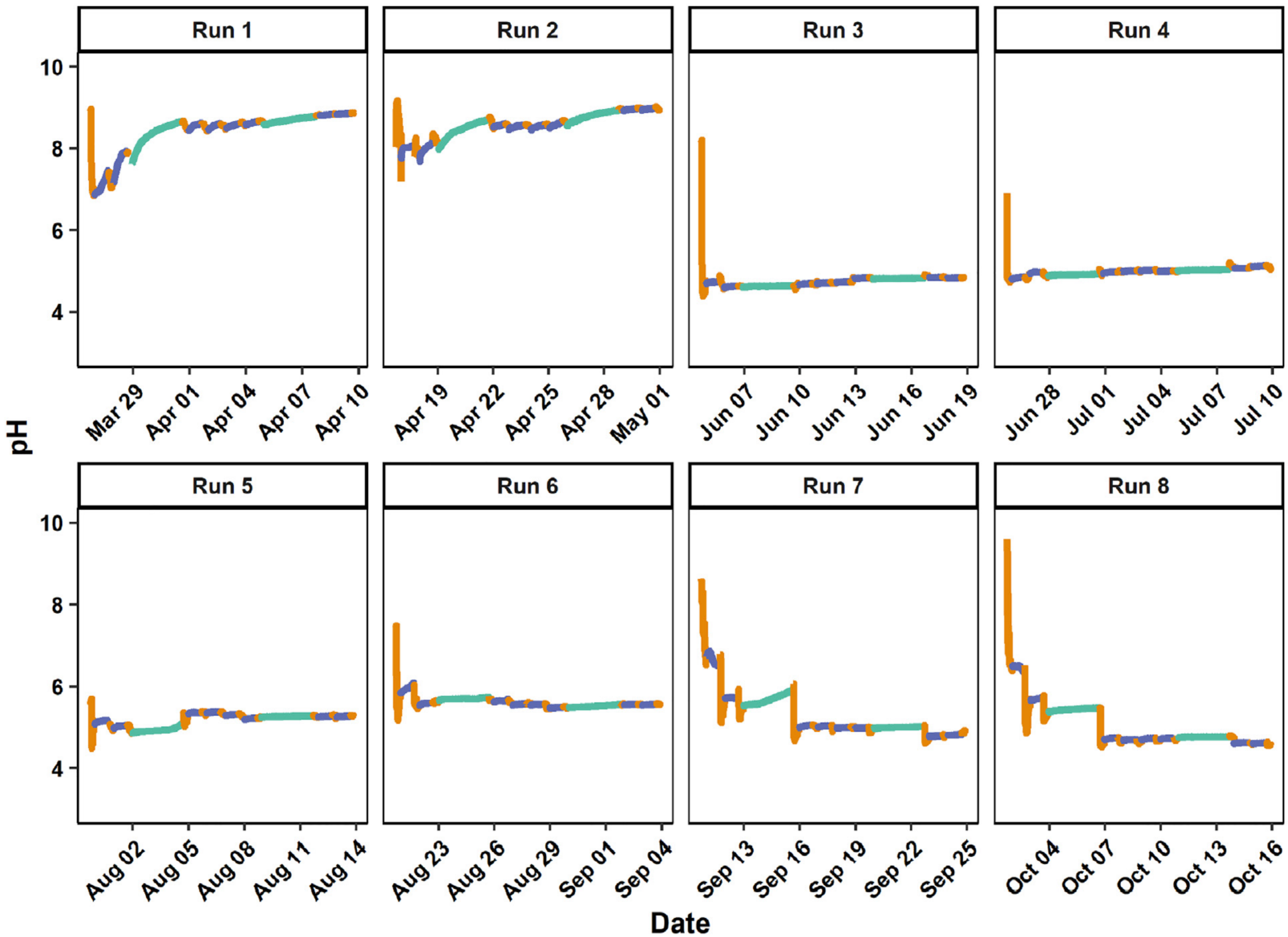
After every user

Runs 5 & 6

Hourly acid addition (day)

Runs 7 & 8

Hourly acid addition (night)



Saetta et al., 2020. *Sci. Total Environ.*

Impact of acetic acid on urine storage

Runs 3 & 4

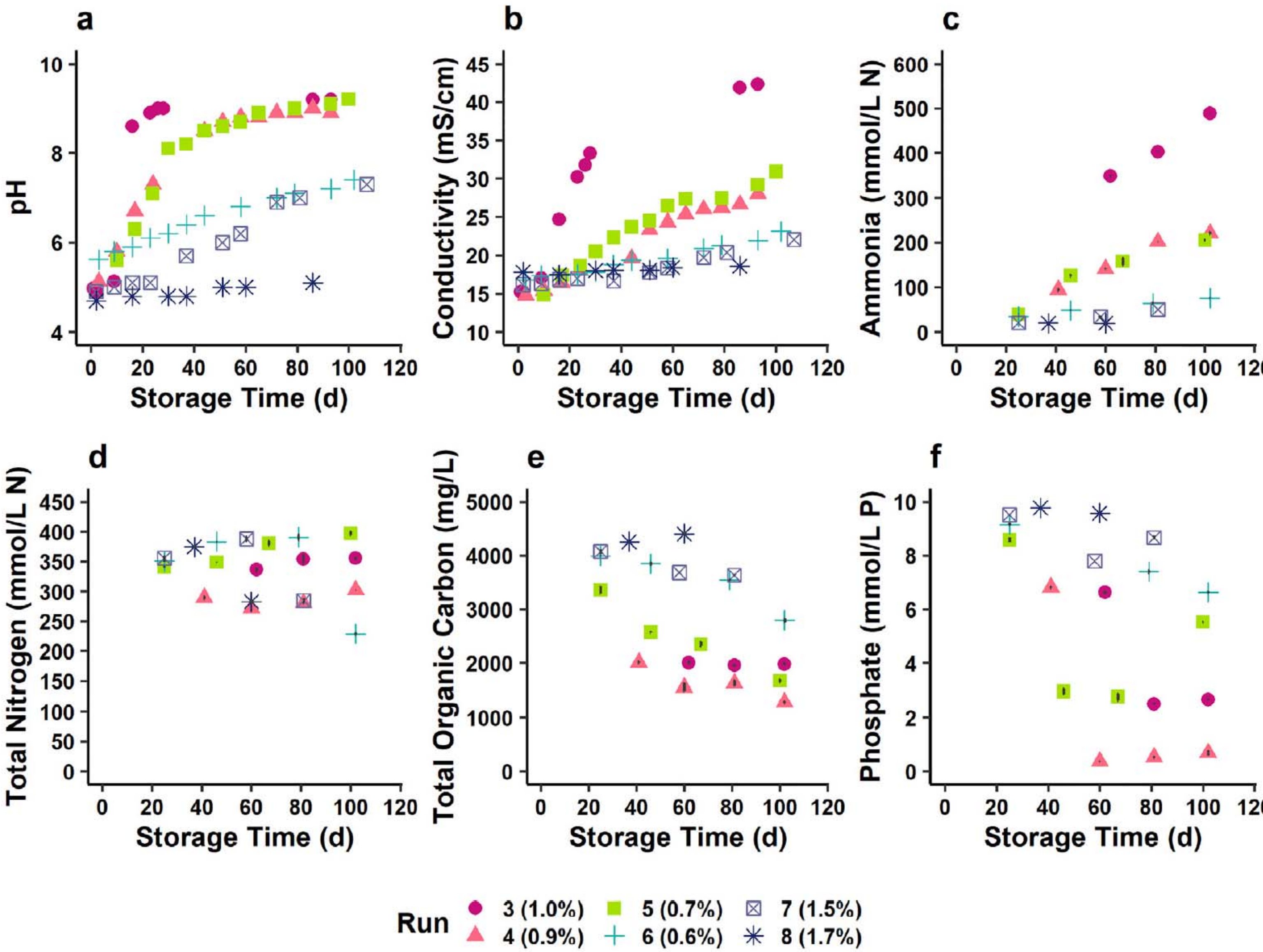
After every user

Runs 5 & 6

Hourly acid addition (day)

Runs 7 & 8

Hourly acid addition (night)

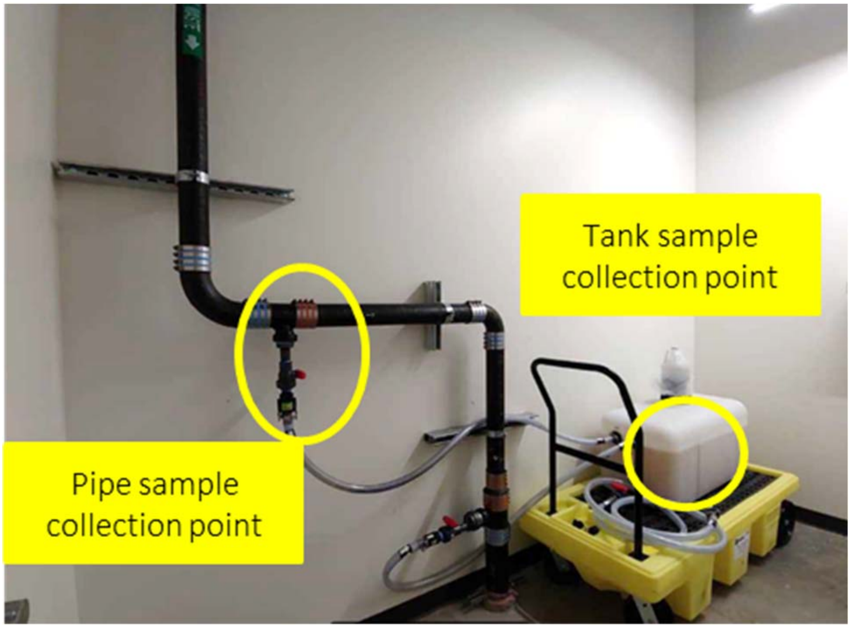


Saetta et al., 2020. *Sci. Total Environ.*

From restroom to building testbed

Urea hydrolysis in pipes and storage tank

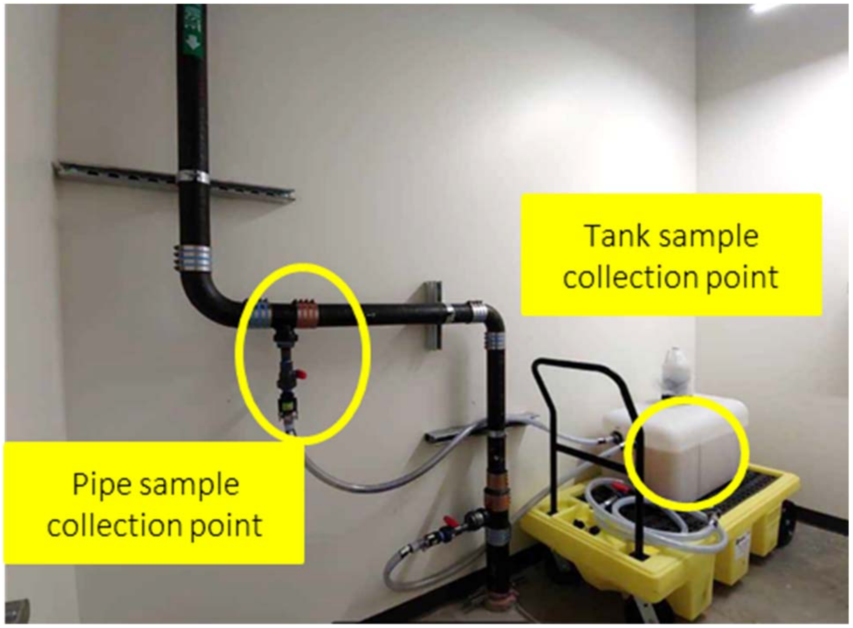
Dr. Neha Jagtap



Location	Urine	pH	Conductivity (mS/cm)	TAN/TN
Tank	8 h collection	8.94	13.5	1.0
	16 h storage	8.87	13.7	1.2
	40 h storage	8.93	14.6	1.1
Pipe	Multiple urination	9.01	12.8	0.97

Jagtap and Boyer, 2020. *J. Environ. Chem. Eng.*

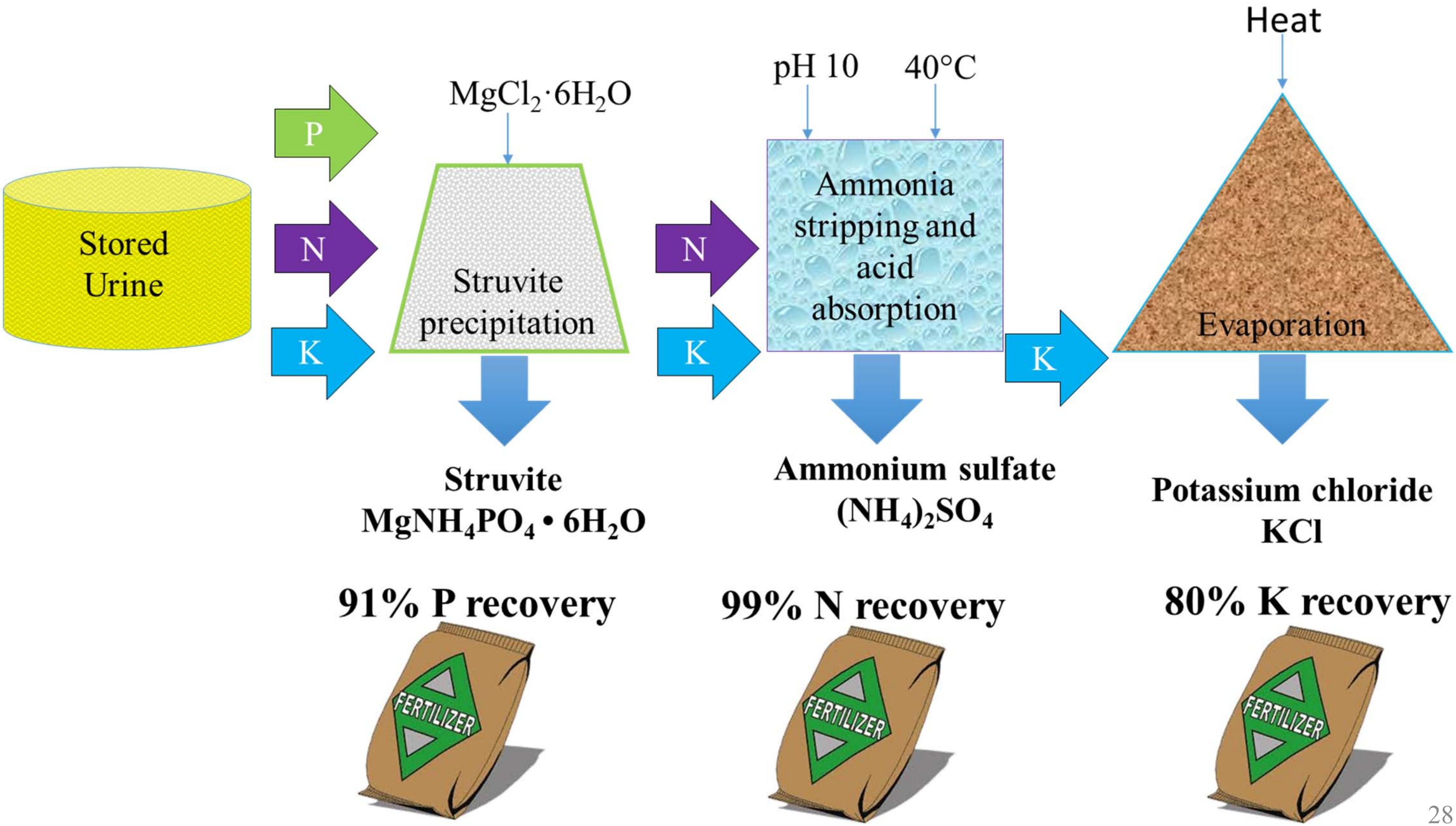
Urea hydrolysis in pipes and storage tank



Sample	Location	pH	Conductivity (mS/cm)	TAN(mg N/L)	TN (mg N/L)	TAN/TN
1	Before pipe	6.4	20	280	5730	0.05
	After pipe	9.0	12	1140	1500	0.8
2	Before pipe	7.0	24	246	9230	0.03
	After pipe	9.1	5.2	546	596	0.9
3	Before pipe	6.6	12	313	4880	0.06
	After pipe	8.9	5.3	509	488	1.0

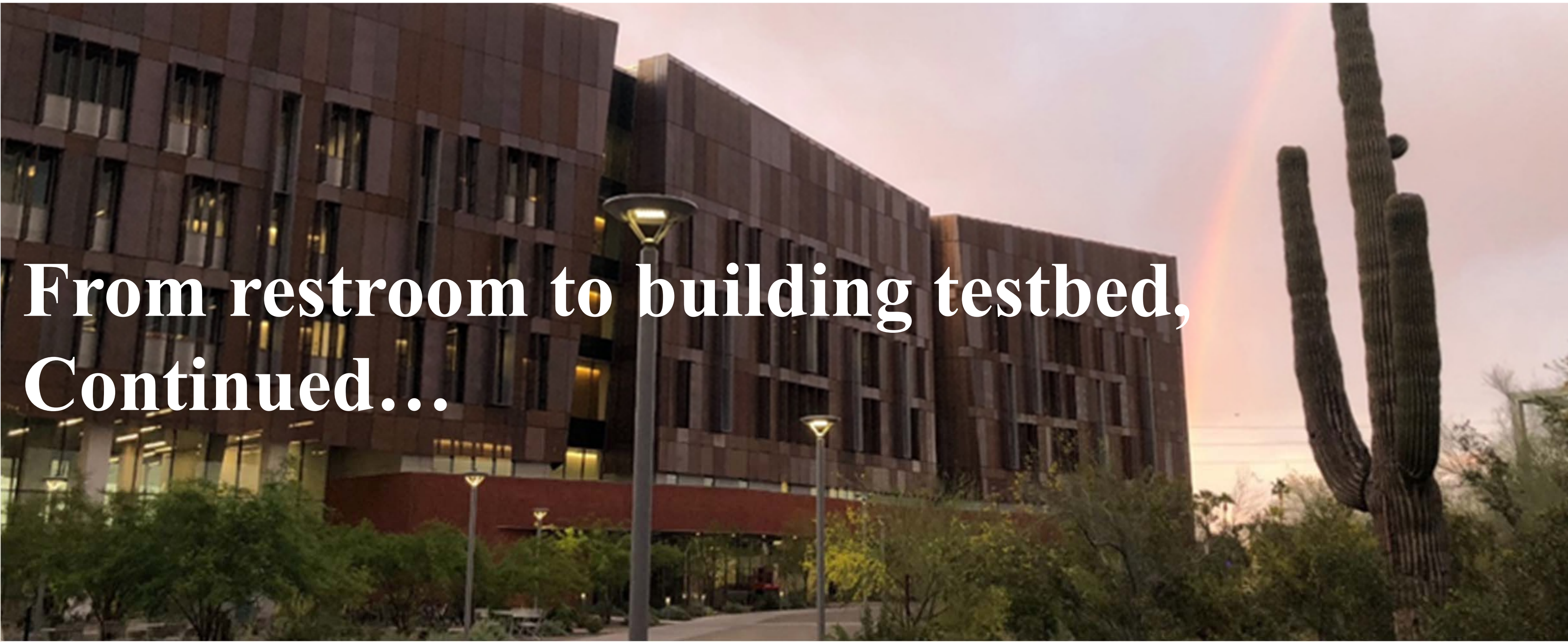
Jagtap and Boyer, 2020. *J. Environ. Chem. Eng.*

Integrated, multi-process approach to total nutrient recovery from urine



Jagtap and Boyer, 2018. *Environ. Sci.: Water Res. Technol.*, 2020. J. Environ. Chem. Eng., 2020.

From restroom to building testbed, Continued…



Current thinking on urine diversion

- **Real opportunities** for urine diversion
  - Potable water savings
  - Nutrient removal and recovery
  - Pharmaceutical removal and toxicity reduction
- Urine diversion is a **process not a product**
- **Benefits derived from extension of system boundary** to include drinking water production, wastewater treatment, fertilizer production, and ecotoxicity reduction
- **Distributed urine diversion system** that includes decentralized treatment and centralized treatment with vacuum truck collection appears viable
- Need to consider **human behavior and interaction**

Questions thboyer@asu.edu