Title: Urine the cloud: Real-time sensing of nonwater urinal for urine diversion systems and water conservation

IEEE SusTech 2017

Daniella Saetta and Arsh Padda

The use of water conserving bathroom fixtures, such as nonwater urinals,[1] has been supported for their potential to conserve large volumes of high quality drinking water. However, unforeseen consequences occurred when poorly designed nonwater urinals were installed to existing infrastructure. One of the biggest problems with installation of nonwater urinals was their propensity to clog due to spontaneous precipitation.[2] This occurs when the urea hydrolysis reaction converts the urea in urine into ammonia and bicarbonate.[3] This reaction is catalyzed by a ubiquitous enzyme and it raises the pH of urine from 6 to 9. The increase in pH causes the calcium and magnesium in urine to precipitate from solution as struvite and hydroxyapatite, among other solids.[4] Clogged urinals create unfriendly environments for users and maintenance is difficult once urinals become clogged. Due to these maintenance issues, nonwater urinals are often retrofitted with flushing mechanisms or have been completely replaced with their water-flushing counterparts, ceasing their ability to conserve potable water.

Nonwater urinals are also critical in the implementation of urine diversion systems. Urine diversion has been proposed as an alternative wastewater treatment process that collects and treats human urine as a separate stream.[5] Why collect and treat urine separately? Urine contributes 80% of the nitrogen and 50% of the phosphorus to a wastewater treatment plant, while only contributing to about 1% of the volumetric flow.[6] Reducing the amount of urine that enters the centralized wastewater collection system has the ability of reducing energy and chemical demands used at water and wastewater treatment plants.[7] Savings at the drinking water treatment plant come from conservation of drinking water otherwise used for flushing toilets and urinals.[8] Once urine is collected, various technologies can be employed to recover nutrients, remove pharmaceuticals, and/or reduce its volume.[9-11] Recovered products can then enter their appropriate market as alternatives to their synthetic counterparts.

The goals of this project were to create a nonwater urinal testbed for improved understanding of urine chemistry and its effects on the urinals, collection system, and storage tanks. Specifically, (1) a cyber-physical system (CPS) was created to monitor urine chemistry in real-time, (2) realistic experiments were conducted to mimic and inhibit urea hydrolysis in the nonwater urinals, and (3) nutrients and metals were tracked throughout the experiments for chemical analysis of urine throughout, as well as physical changes to the collection system. Based on the concept of Internet of Things, we use Raspberry Pi to collect data from pH and conductivity sensors at a given frequency. Pub/Sub was used to send data to the Cloud. The advantages of Pub/Sub are that it ensures at least one delivery of the data packet and it can adjust itself to the incoming traffic of data. Once the data packet reaches the Cloud platform, it is stored in the data store. The data in data store is secure, flexible, and readily available. It can be retrieved in any desired format. Data manipulation, data analysis and data visualization can be performed in the Cloud. Experiments were run to determine the effects of inhibiting the urea hydrolysis reaction by acid addition on cast iron and plastic pipe materials. Realistic conditions were recreated using wireless controllers, which automated urine and acid delivery pumps. Samples were taken from within the pipe network for nutrient and heavy metal measurements to determine the change in concentrations from urinals to pipes to storage tanks.

1. ASME, Vitreous china nonwater urinals. In New York, NY, 2006; Vol. A112.19.19-2006.
2. Bristow, G.; McClure, J. D.; Fisher, D., Waterless Urinals: Features, Benefits, and Applications. *Journal of Green Building* **2006,** *1*, (1), 55-62.
3. Udert, K. M.; Larsen, T. A.; Biebow, M.; Gujer, W., Urea hydrolysis and precipitation dynamics in a urine-collecting system. *Water Res* **2003,** *37*, (11), 2571-82.
4. Udert, K. M.; Larsen, T. A.; Gujer, W., Estimating the precipitation potential in urine-collecting systems. *Water Res* **2003,** *37*, (11), 2667-77.
5. Larsen, T. A.; Gujer, W., Separate management of anthropogenic nutrient solutions (human urine). *Water Science and Technology* **1996,** *34*, (3-4), 87-94.
6. Wilsenach, J. A.; van Loosdrecht, M. C. M., Integration of processes to treat wastewater and source-separated urine. *Journal of Environmental Engineering-Asce* **2006,** *132*, (3), 331-341.
7. Ishii, S. K.; Boyer, T. H., Life cycle comparison of centralized wastewater treatment and urine source separation with struvite precipitation: Focus on urine nutrient management. *Water Res* **2015,** *79*, 88-103.
8. Landry, K. A.; Boyer, T. H., Life cycle assessment and costing of urine source separation: Focus on nonsteroidal anti-inflammatory drug removal. *Water Res* **2016,** *105*, 487-495.
9. Basakcilardan-Kabakci, S.; Ipekoglu, A. N.; Talini, I., Recovery of ammonia from human urine by stripping and absorption. *Environmental Engineering Science* **2007,** *24*, (5), 615-624.
10. Wilsenach, J. A.; Schuurbiers, C. A.; van Loosdrecht, M. C., Phosphate and potassium recovery from source separated urine through struvite precipitation. *Water Res* **2007,** *41*, (2), 458-66.
11. Landry, K. A.; Sun, P.; Huang, C. H.; Boyer, T. H., Ion-exchange selectivity of diclofenac, ibuprofen, ketoprofen, and naproxen in ureolyzed human urine. *Water Res* **2015,** *68*, 510-21.