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Increasing resilience with wastewater reuse

Katherine A. Klise

Drinking water infrastructure in urban settings is increasingly affected by population growth and disruptions like extreme weather events. The integration of direct wastewater reuse can help to maintain drinking water service when the system is compromised.

The ability to meet basic water needs is crucial to sustaining human health, agriculture, the economy, the environment, and government stability. However, the water systems we rely on increasingly face challenges. Urbanization and climate change have intensified water scarcity[1]. Additionally, water systems are vulnerable to natural disasters, cyber threats and degradation[2]. Major disruptions can affect water service on the order of days, weeks or more. Examples include the 2014 magnitude 6.0 earthquake in South Napa, California[3], the 2014 water contamination in Flint, Michigan[4], the 2017 hurricanes in the Caribbean[5], the 2021 cyber-attack in Oldsmar, Florida[6], and the 2023 wildfire in Lahaina, Hawaii[7]. The use of unconventional water sources, such as water with high salt content and wastewater, has been proposed as a way to meet demand when conventional water sources are compromised. Now, writing in *Nature Water*, Liu et al.[8] have shown that the integration of unconventional water sources can also increase the resilience of water distribution systems.

Resilience is commonly thought of as the ability of a system to bounce back. A more formal definition describes a system that has the "ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event"[2] as measured by the magnitude and duration of the disruption. Resilience can be quantified using a resilience performance curve, as shown in Fig. 1. This curve requires well defined metrics that track performance along the *y*-axis. These metrics can be a function of network structure, hydraulics, water quality or effects on the community and can integrate information from numerical simulations and census data. Liu et al. use several metrics to track performance, including water service availability (the ratio of the actual volume of water a customer receives to the expected water volume within a given timeframe), population affected by the disruption, and contaminant concentration. These metrics are used to extract the magnitude and duration of disruptions with respect to each quantity of interest.

For this analysis, Liu et al. partnered with the City of Houston in Texas, USA, to explore how direct wastewater reuse could increase resilience of the water distribution system. The analysis considers two systems: the current centralized system, which relies on a conventional water source, and a hybrid system, which integrates distributed direct wastewater reuse within the current system. The use of a highly detailed water distribution system model is very important to this study. Water distribution system models simulate complex hydraulic networks, including pipes, pumps, valves and tanks along with water demands that represent residential, industrial and commercial users. Although this makes the model and results very location-specific, the case study provides an important

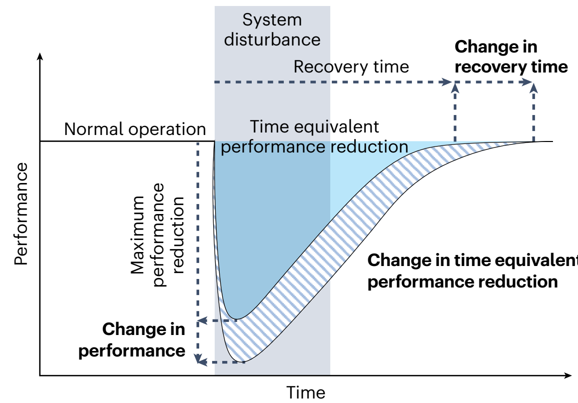

Fig. 1 | Performance curves used to quantify resilience under different conditions, based on the change in performance and the recovery time after a disruption. In Liu et al., system resilience is quantified in water distribution systems with and without the integration of wastewater reuse. Figure adapted from ref. 8, Springer Nature Ltd.

framework that other utilities can use to conduct similar analyses. Furthermore, the authors argue that the case study emphasizes the importance of re-evaluating our centralized urban water systems and propound alternative, hybrid configurations of water treatment and production that support higher system reliability and resilience.

Three disruptive scenarios were considered in the analysis: pump station failures, pipe leakage and source water contamination. These scenarios represent the types of damage that have been seen in recent disruptive events, although extended duration and compound failures were not included. The analysis illustrates that the hybrid system generally improves resilience. For example, pump station failures have less negative impact on water pressure in a hybrid system owing to the addition of pressurized water from multiple sources. However, some differences in system performance were small. For example, a change in water service availability that reflects only a 1% decline in water demand for a short period of time needs further investigation before costly infrastructure upgrades are undertaken. Longer duration or more severe disruptive scenarios that mimic significant events or climate projections might provide additional insight into the resilience-enhancing benefits of a hybrid system.

Several challenges remain for the widespread adoption of direct wastewater reuse, including public perception, water quality concerns and cost[9]. That said, water systems need to evolve with changes in supply, demand, technology and policy to meet projected water needs in growing urban centres. The framework developed by Liu et al. should help to inform major system upgrades from an operations and resilience perspective.

Katherine A. Klise

Sandia National Laboratories, Albuquerque, NM, USA.

e-mail: kaklise@sandia.gov

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Competing interests

The author is a software developer of the Water Network Tool for Resilience (WNTR), which was used in Liu et al. for resilience analysis.