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Science for Environment Policy

Decentralised supply of recycled water may save energy and reduce greenhouse gas emissions

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Reusing waste water for non-drinking uses in decentralised plumbing networks may improve the efficiency of water supply in urban areas, a new study has found. Modelling this approach in San Francisco, researchers found that, depending on the local geography, a decentralised water supply could lead to energy savings and reductions in greenhouse gas emissions from water treatment of around 30%. Improvements in emerging water-treatment technologies are likely to lead to further savings, which could help increase the efficiency of urban water supply.

Water resources are at risk globally due to climate changes and population growth. Droughts are also increasing in both their severity and frequency in many parts of the world. As such, increasing the resilience and security of water supplies is a priority, particularly in densely populated areas. Conventional water and waste water services have significant greenhouse gas (GHG) emissions from energy use, due to pumping and treatment processes. Reusing part of the waste water could help to reduce the freshwater demand, particularly during times of drought.

Currently centralised sewage networks, which are often located at low elevations to enable efficient collection of waste water from the surrounding area using gravity, are used to collect waste water. The waste water is then treated in large treatment plants before being discharged into the environment.

Non-potable reuse (NPR) involves using recycled water to, for example, flush toilets and irrigate crops — actions which require a lower level of water treatment than tap water, which requires advanced treatments to ensure it is fit for drinking. NPR may reduce energy consumption and costs due to this less advanced water treatment and to lower regulatory requirements before reuse; however, this approach requires additional plumbing systems to accommodate separate distribution from drinking water. Decentralised systems have been suggested as a an efficient way of distributing NPR water as they are closer to reuse customers.

This study compared NPR water supply to residential areas under two scenarios: (1) a centralised system using existing waste-treatment plants, with additional pipelines for delivering recycled water; and (2) a decentralised system using new treatment facilities and pipelines close to the water delivery point. The decentralised system was modelled on using a membrane bioreactor, which uses ultraviolet light and chlorine to disinfect water. Energy use and GHG emissions of the two systems were modelled depending on factors including level of decentralisation, size of treatment facilities, piping network required, population density, topography and types of NPR.

The analysis was applied to neighbourhoods in San Francisco, USA, which is a leading innovator in water reuse, including NPR. The piping length and pumping pressure required was estimated for both systems. In addition, a life-cycle model estimated the environmental impacts of the infrastructure required, including GHG emissions for material production and delivery, construction, operation and maintenance.

Continued on next page.

Source: Kavvada, O., Horvath, A., Stokes-Draut, J., Hendrickson, T.P., Eisenstein, W.A. & Nelson, K.L.(2016). Assessing Location and Scale of Urban Nonpotable Water Reuse Systems for Life-Cycle Energy Consumption and Greenhouse Gas Emissions. *Environmental Science & Technology*, 50 (24):13184–13194. DOI:10.1021/acs.est.6b02386

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The researchers say the optimal scenario for a decentralised supply is a large facility (around 2 000 cubic metres of water per day (m^3/day), which represents a facility serving up to 10 000 people) at higher elevations. In this situation, the researchers calculated savings of between 0.5 and 0.7 kilowatt-hour per m^3 and 0.06 to 0.07 kilograms carbon dioxide equivalent per m^3 in energy and GHG emissions compared to the centralised system. This corresponds to almost 29% lower energy use and 28% lower GHG emissions in more elevated parts of the city. However, smaller facilities (20 m^3/ day) at lower elevations had up to 85% higher energy use and 49% higher GHG emissions compared to a centralised system.

Overall, the study found that geographic factors such as elevation and distance from residences were more important than economies of scale, which would otherwise make centralised systems more efficient. For a centralised system, pumping contributes up to 60% of energy consumption, meaning topography is a crucial factor in energy use. The treatment of water in the decentralised system contributes up to 85% of total energy. This makes centralised treatments better in low areas and, due to economies of scale, when located closer to the main plant. In contrast, residential areas at higher elevations or far away from treatment plants may be better served by decentralised systems. The researchers also say that decentralised systems may become more competitive if emerging treatment technologies, such as the membrane bioreactor modelled in this study, continue to improve.

The researchers say that the approach developed here could be applied to other cities. However, they caution that the results of this study are based on a number of assumptions regarding the performance of waste-water-treatment technologies, which they say could be improved as more information becomes available on their use in practice. Direct GHG emissions from treatment facilities was not considered, which the researchers describe as a major source of uncertainty, as microbial activity during treatment can lead to significant emissions. They consider thelikely emissions from different types of treatment plants a priority for research.

In the future, infrastructure planners will have to seek opportunities to improve efficiency in the provision of services. The researchers say that a decentralised approach in a densely populated city such as San Francisco, which is an innovator in water reuse, allows for a more flexible means of expanding the water system as demand arises for NPR.

Source: Kavvada, O., Horvath, A., Stokes-Draut, J., Hendrickson, T.P., Eisenstein, W.A. & Nelson, K.L.(2016). Assessing Location and Scale of Urban Nonpotable Water Reuse Systems for Life-Cycle Energy Consumption and Greenhouse Gas Emissions. *Environmental Science & Technology*, 50 (24):13184–13194. DOI:10.1021/acs.est.6b02386

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