PHOTO: PERMEATE PARTNERS

Advanced technologies can convert raw sewage (left container) into drinking water (right container) by removing the vast majority of pollutants (center container) in the process. Proactive policies to identify, prevent, and monitor trace levels of remaining contaminants in drinking water are needed to protect public health.

WATER QUALITY

# Protecting the sewershed

## As cities use sewage as a water source, proactive policies must safeguard public health

*By* **Sasha Harris-Lovett**[1] *and* **David Sedlak**[1,2]

Urban population growth and less-reliable precipitation patterns due to climate change are putting pressure on the drinking water supplies of cities worldwide (*1*). At the same time, water treatment technologies are improving and becoming cheaper. These combined conditions have led urban water supply managers to look favorably on a nontraditional drinking water source: sewage (*2*). Purifying sewage to meet drinking water quality standards, a process known as potable water reuse, is technically feasible and can be cost-effective for augmenting urban water supplies. For these reasons, potable water reuse systems are becoming popular in the United States, Singapore, and Australia, among other places (*3*).

These new water supplies require reassessment of the policies and strategies for management of sewage and drinking water. Traditionally, water supply managers and regulators in the United States and much of the world have assumed that cities would get their drinking water from the most pristine sources available. When contaminants of health concern were detected, regulators imposed additional standards for drinking water treatment, such as maximum contaminant levels for a particular chemical (*4*).

Using sewage as a water source requires a different approach. In the era of potable water reuse, a proactive regulatory strategy is especially necessary to protect public health, and regulations must adapt to take this practice into account. Sewage is, by definition, highly polluted. Although water treatment technologies can produce recycled water that meets current drinking water standards, the existing approaches of waiting until health impacts are recognized before acting to regulate a particular chemical found in the recycled water (as is current practice in the United States) may not adequately protect public health. In the European Union, the approach of prohibiting potable reuse systems because they are deemed too risky is also not wholly effective because of the prevalence of unplanned water reuse (*5*).

As planned potable water reuse systems become more common, water management must undergo a paradigm shift. This is not the first time the water industry has faced this type of challenge. In the late 20th century, water managers and regulators in the United States recognized that preventing pollution of water supplies from diffuse sources, such as farm runoff and pastures, was often more effective and cheaper than finding ways to purify contaminated drinking water (*6*). The push for watershed protection in the 1990s changed the way that water utilities managed drinking water and provides lessons for protecting drinking water in the era of potable water reuse.

Watershed protection regulations such as the 1996 amendment to the Safe Drinking Water Act prevented pollution throughout the hydrologic basin from which cities obtained drinking water (*6*). In the United States, federal funds were allocated to help water managers meet new watershed protection requirements (*6*). These policies changed the status quo: Many water utilities restructured their organizations to acquire and manage land, to develop expertise in rangeland conservation and forestry, and to work closely with stakeholders throughout the watershed.

Wastewater was left out of previous watershed protection efforts. Because it is increasingly integral to urban water supplies, it now merits explicit consideration. This nontraditional water source requires an extension of watershed protection programs to include the "sewershed"—the network of sewers and sewage collection infrastructure in cities. Today, a sewershed protection approach is needed alongside existing watershed protection programs to preserve the safety of drinking water supplies.

Sewershed protection is a proactive regulatory approach to address the potential health risks associated with contaminants in sewage. Sewershed protection, paired with water treatment technologies, can safeguard drinking water supplies by curbing discharges of chemicals that have the potential to pass through water treatment systems. The same features of watershed protection should apply to sewershed protection: prioritizing resource allocation, ensuring stakeholder involvement in the development of goals, and finding integrated solutions.

For potable water reuse systems, much of the attention on chemical contamination has focused thus far on characterizing and removing pharmaceuticals, personal care products, and disinfection by-products (*2*).

[1]Berkeley Water Center, University of California, Berkeley, CA, USA. [2]Department of Civil and Environmental Engineering, University of California, Berkeley, CA, USA. Email: sedlak@berkeley.edu

Downloaded from http://science.sciencemag.org/ on September 21, 2020



Published by AAAS

The presence of these chemical compounds is relatively uniform across sewersheds, and gains made in understanding the sources of these compounds and options for treating them will apply to a range of cities considering or employing potable water reuse.

This is an important step, but it is insufficient to ensure the ongoing safety of potable water reuse systems. Characterization and control of industrial chemicals in sewersheds are also necessary (*7*). Chemicals intentionally discharged or accidentally released by factories or commercial enterprises to sewersheds are less predictable than chemicals sourced from households. Industrial chemical discharges to sewers vary greatly depending on which industries are present; sewersheds with industrial discharges may have concentrations of chemicals that are several orders of magnitude larger than those without industrial discharges (*8*).

Although the 1972 Clean Water Act regulates discharges of contaminants into surface waters in the United States to protect aquatic ecosystems, there is no comparable regulation to ensure that what goes into sewers is safe to be used as an eventual drinking water supply. Most existing industrial waste discharge permits and wastewater source control programs are relics of a previous era when the primary concern was the introduction of chemicals that could prevent the microbes at the sewage treatment plant from doing the work of cleaning wastewater. Regulations for sewershed protection must take into account the potential risks that chemicals in the sewershed pose to public health, as well as the cost and effectiveness of existing technologies to purify wastewater to drinking water standards (*9*). In sewersheds with higher risk of drinking water contamination due to large volumes of industrial chemical discharges to a sewershed relative to the volume of municipal wastewater, sewershed protection regulations might prohibit potable water reuse or require more extensive treatment and monitoring.

Some cities have begun to pursue proactive sewershed protection policies. For example, in Orange County, California, where potable water reuse has been practiced for more than 40 years, the wastewater utility has imposed strict limits on industrial discharges of toxic chemicals that have the potential to pass through its advanced treatment system. Similar practices have been less extensive in other cities that are planning and operating potable water reuse systems (*10*).

The concept of sewershed protection should not be restricted to places that are planning or operating potable water reuse systems. Treated wastewater is ubiquitous in surface waters, as evidenced by the presence of organic chemical contaminants derived from treated wastewater in more than 80% of streams in the United States (*11*). Wastewater effluent dominates the flow of more than 900 streams in the United States and many European rivers at some times of year (*5*, *12*). Many cities already rely upon water that originates in a sewershed; for example, Philadelphia, Berlin, and Houston all draw drinking water from surface waters with substantial contributions of wastewater effluent (*2*, *5*, *13*).

The sewershed protection concept also has implications for the quantity of recycled water that is potentially available. Household-scale water reuse and indoor water conservation can be important practices that are strongly supported within communities; however, a sewershed approach that explicitly acknowledges and plans for sewage being part of the water supply is essential to coordinating investments in water conservation and potable water reuse to produce a reliable supply of safe drinking water. Household- and neighborhood-scale water conservation efforts, such as greywater recycling and low-flow appliances, can reduce flows to municipal wastewater treatment plants, thereby concentrating pollutants and reducing the overall quantity of water available for municipal water reuse. Even under circumstances where industrial discharge to sewers is not a major concern, more efficient indoor water use has the potential to concentrate pollutants in sewage (*6*).

Recognition that sewers are part of the water supply requires important changes to U.S. policy, including the Clean Water Act and the Toxic Substances Control Act, and dictates a need for additional scientific research to protect drinking water supplies and public health. Regulators must implement policies to mandate more extensive monitoring and disclosure of chemicals discharged to sewers by commercial and industrial operations. Wastewater utilities must work with stakeholders to initiate real-time monitoring of chemicals in sewage, and create a mechanism for diverting or providing additional treatment at potable water reuse systems if release of a chemical occurs as the result of a spill.

Scientists and funding agencies must intensify research on the identification, fate, transformation, and health effects of chemicals in wastewater to enable more informed decision-making about potable water reuse. Special attention should be given to sewersheds that have a high contribution of wastewater from industrial, commercial, and medical sources, and these should not be considered for water reuse if there is not clear evidence of robust water treatment, reliable system operations and maintenance, and rapid disaster response capacity. Chemicals that have the greatest likelihood of passing through advanced water treatment facilities, or that produce toxic by-products during the water treatment process, must be identified, monitored, and controlled. This would enable more reliable water quality and create the possibility of tailoring treatment plants to the local composition of sewage in a particular sewershed.

Finally, support for the development of biodegradable, nontoxic chemical alternatives for compounds that are difficult to remove during water treatment is urgently needed. Policies to support green chemistry would lessen potential health risks associated with using sewage as a water supply. Regulations similar to Europe's REACH legislation, which place the burden of proof of chemical safety on the manufacturer, may be more protective of health than the U.S. Toxic Substances Control Act (*14*) and are therefore more appropriate in the era of potable water reuse, provided that sewershed safety is considered.

Changes such as these are foundational to a sewershed protection approach. They will help to mitigate the risks posed by using sewage as a source of water supply, identify sewersheds where potable water reuse is a less desirable option, and protect public health in the era of potable water reuse. ■

Downloaded from http://science.sciencemag.org/ on September 21, 2020

## REFERENCES AND NOTES


1. C. J. Vörösmarty, P. Green, J. Salisbury, R. B. Lammers, *Science* **289**, 284 (2000).
2. National Research Council, *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater* (2012); https://bit.ly/3hwFZgB.
3. A. N. Angelakis, T. Asano, A. Bahri, B. E. Jimenez, G. Tchobanoglous, *Front. Environ. Sci.* **6**, 26 (2018).
4. U.S. Public Health Service, *Public Health Service Drinking Water Standards* (1962), vol. 2.
5. J. E. Drewes *et al.*, *Characterization of Unplanned Water Reuse in the EU—Final Report* (European Commission Directorate-General for Environment, 2017); https://bit.ly/3jBrQRd.
6. U.S. Environmental Protection Agency, *Understanding the Safe Drinking Water Act* (2004).
7. C. E. Scruggs *et al.*, *J. Am. Water Works Assoc.* **112**, 10 (2020).
8. P. J. Phillips *et al.*, *Environ. Sci. Technol.* **44**, 4910 (2010).
9. E. L. Marron, W. A. Mitch, U. V. Gunten, D. L. Sedlak, *Acc. Chem. Res.* **52**, 615 (2019).
10. S. R. Harris-Lovett, C. Binz, D. L. Sedlak, M. Kiparsky, B. Truffer, *Environ. Sci. Technol.* **49**, 7552 (2015).
11. D. W. Kolpin *et al.*, *Environ. Sci. Technol.* **36**, 1202 (2002).
12. J. Rice, P. Westerhoff, *Nat. Geosci.* **10**, 587 (2017).
13. U.S. Environmental Protection Agency, *2012 Guidelines for Water Reuse*; https://bit.ly/32UoF11.
14. M. R. Schwarzman, M. P. Wilson, *Science* **326**, 1065 (2009).


## ACKNOWLEDGMENTS

We thank S. Matsoyan for research support. Funding for this research was provided by the NSF Engineering Research Center for Reinventing the Nation's Urban Water Infrastructure (ReNUWIt) under grant EEC-1028968.

10.1126/science.abd0700



Published by AAAS

Science

# Protecting the sewershed

Sasha Harris-Lovett and David Sedlak

*Science* **369** (6510), 1429-1430.
DOI: 10.1126/science.abd0700

**ARTICLE TOOLS** http://science.sciencemag.org/content/369/6510/1429

**REFERENCES** This article cites 9 articles, 2 of which you can access for free
http://science.sciencemag.org/content/369/6510/1429#BIBL

**PERMISSIONS** http://www.sciencemag.org/help/reprints-and-permissions

Use of this article is subject to the Terms of Service

*Science* (print ISSN 0036-8075; online ISSN 1095-9203) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. The title *Science* is a registered trademark of AAAS.

Copyright © 2020, American Association for the Advancement of Science

Downloaded from http://science.sciencemag.org/ on September 21, 2020