

## Water Reuse

### Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater

Expanding water reuse—the use of treated wastewater for beneficial purposes including irrigation, industrial uses, and drinking water augmentation—could significantly increase the nation's total available water resources. A portfolio of treatment options is available to mitigate water quality issues in reclaimed water, and new analysis suggests the risk of exposure to certain microbial and chemical contaminants from drinking reclaimed water does not appear to be any higher than the risk experienced in at least some current drinking water treatment systems, and may be orders of magnitude lower. Adjustments to the federal regulatory framework could enhance public health protection for both planned and unplanned (or de facto) reuse and increase public confidence in water reuse.

With global population increasing and climate changing, many communities are facing water supply challenges. As a result, water reuse is attracting increasing attention. Reusing municipal wastewater instead of discharging it offers an opportunity to augment the water supply of communities facing water shortages, particularly in coastal areas.



Water reuse for applications such as irrigation is well established in many communities.

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Water reuse for applications other than drinking, such as irrigating golf courses or industrial cooling (known as nonpotable applications), is already well established, but planned water reuse for drinking water augmentation (known as potable reuse) is less common in the United States. However, the unplanned potable reuse of treated wastewater—for example when a drinking water system uses a surface water supply that receives upstream wastewater discharges—is common in many of the nation's water systems. Here, the committee that wrote the report refers to unplanned potable reuse as de facto reuse. There has been no systematic analysis of the extent of de facto reuse in the United States for over 30 years.

#### Treatment and Water Quality Assurance

Municipal wastewater contains a wide range of biological and chemical compounds, some of which could be harmful to public health and

ecosystems. Based on the intended use of the water, water managers can choose from a portfolio of treatment options to design a wastewater reclamation system that meets specific water quality objectives. For example, the presence of some compounds in reclaimed water may be of concern in drinking water, but not in water intended for

landscape irrigation. Advanced treatment processes are also capable of addressing contemporary water quality issues related to potable reuse involving pathogens or trace organic chemicals.

#### Quality Assurance

To ensure the quality of reclaimed water, treatment systems should include multiple barriers for pathogens that cause waterborne diseases in order to strengthen the reliability of contaminant removal, and should employ diverse combinations of technologies to address a broad variety of contaminants. Reclamation facilities should develop monitoring and operational plans to respond to variability, equipment malfunctions, and operator error to ensure that reclaimed water meets the appropriate quality standards for its use. A critical aspect of such systems is the identification of easily measurable parameters (also called

surrogates) that can indicate treatment failures and trigger corrective actions.

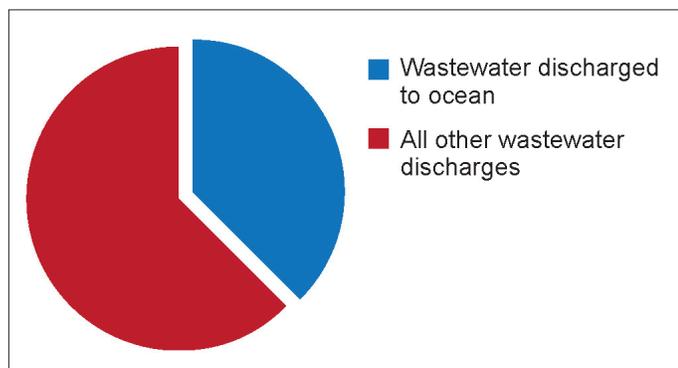
### ***Natural Systems for Water Treatment and the Role of the Environmental Buffer***

In many potable water reuse systems, water is discharged after treatment to a natural system such as an aquifer, a reservoir, or a wetland, providing a buffer between water treatment and consumption. Environmental buffers can further remove contaminant levels such as pathogens from the water and provide additional retention time, and they also have been beneficial for public acceptance of water reuse. In some cases, engineered natural systems can replace advanced treatment processes. However, the science necessary to design engineered natural systems to provide a uniform level of public health protection is not available at present.

It cannot be demonstrated that natural barriers provide any protection that is not also available by engineered processes. Environmental buffers can be useful elements that should be considered along with other processes and management actions in the design of potable reuse projects, but they are not essential elements to achieve quality assurance. As long as adequate protection is engineered within the system, the committee concluded that potable reuse of highly treated reclaimed water without an environmental buffer is worthy of consideration. Additionally, the classification of potable reuse projects as indirect (i.e., includes an environmental buffer) and direct (i.e., does not include an environmental buffer) is not productive from a technical perspective, because the terms are not linked to product water quality.

### **Understanding the Risks**

Well established principles and processes exist for estimating the risks of water reuse applications. Assessing risks helps decision makers evaluate whether



**Figure 1.** Of the 32 billion gallons of municipal wastewater discharged nationwide each day, approximately 12 billion gallons are discharged to an ocean or estuary—an amount equivalent to 6 percent of total water use in the United States. Reusing this water would directly augment the nation’s total water supply.

the estimated likelihood of harm is socially acceptable or may be justified by other benefits. However, risk assessment forms only one of several inputs to the decision-making process, in addition to other factors such as cost, equitability, legal and regulatory factors, and qualitative public preferences.

Modern technology allows the detection of chemical and biological contaminants at extremely low levels, but the detection of a contaminant in reclaimed water does not, in and of itself, indicate a significant risk. Information on the dose of a contaminant required to cause health effects allows scientists to determine if the level of contaminant is significant.

### ***Understanding the Risks of Potable Reuse in Context***

The committee compared the estimated risks of a conventional drinking water source that contains a small percentage of treated wastewater (i.e., de facto potable reuse) against the estimated risks of two different potable reuse scenarios. The analysis suggests that the risk of exposure to 24 selected chemical contaminants in the two planned potable reuse scenarios does not exceed the risk encountered from existing water supplies. With respect to pathogens, although there is a great degree of uncertainty, the risk from potable reuse does not appear to be any higher, and may be orders of magnitude lower than currently experienced in at least some current (and approved) drinking water treatment systems (see Figure 2). This helps demonstrate that state-of-the-art water reclamation systems can provide a comparable level of protection from contaminants to that experienced in many drinking water supplies today, assuming that quality assurance strategies ensure the reliability of the treatment processes.

### ***Risks from System Failures***

When assessing risks associated with reclaimed water, the potential for failures in reliability and unintended uses also needs to be assessed and mitigated. For example, inadvertent cross-connections of potable and nonpotable water lines could allow people to drink water that was intended only for irrigation, presenting human health risks from exposure to pathogens. If the risk is deemed unacceptable, some combination of more stringent treatment barriers or more stringent controls against inappropriate uses may be necessary. Also, treatment system failures could cause a short-term risk to those exposed, particularly for pathogens where a single exposure is needed to produce an effect. A better understanding of the treatment system performance is needed to quantify the uncertainty in risk assessments of potable and nonpotable water reuse projects.

### **Costs**

The financial costs of water reuse vary widely because they depend on site-specific factors, including the location, water quality objectives, and method of treatment applied. In some cases, the costs of nonpotable water

reuse could be more than those for potable reuse. Setting up a nonpotable water reuse system involves constructing separate water distribution lines, which can be a significant expense.

To determine the most socially, environmentally, and economically feasible water supply option, the non-monetized costs and benefits of reuse projects should be considered. For example, water reuse can offer improved reliability, especially during drought, and provides a locally controlled water supply, although it may also reduce water flows to downstream users and ecosystems.

### Social, Legal, and Regulatory Factors

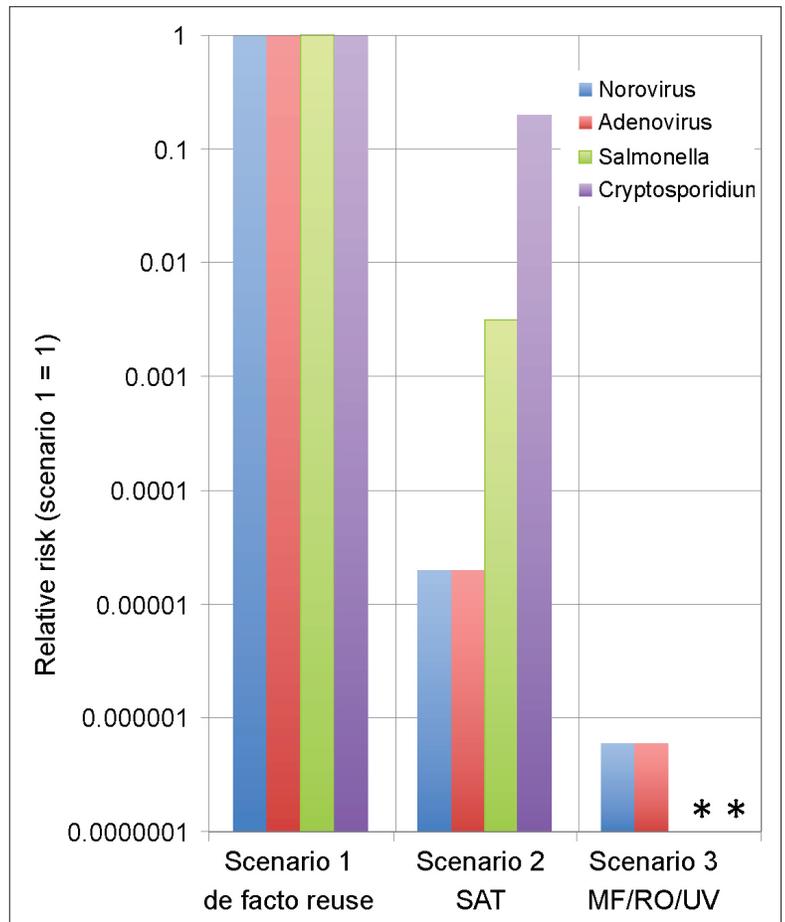
Water reuse projects, like any large-scale water project, affect numerous stakeholders and are affected by a complex legal and regulatory framework that spans many sectors.

#### Regulations for Nonpotable Water Reuse

State regulations for nonpotable reuse are not uniform across the country, and no state water reuse regulations or guidelines for nonpotable reuse are based on rigorous risk assessment methodology. The Environmental Protection Agency has published suggested guidelines for nonpotable reuse that are based, in part, on a review and evaluation of existing state regulations and guidelines, but not on risk assessment methodology. Federal regulations would not only provide a uniform minimum standard of protection, but would also increase public confidence that water reuse does not compromise public health. This process should be informed by scientific research on potential nonpotable reuse applications and practices, which would require resources beyond the reach of most states. The committee recommended that the Environmental Protection Agency fully consider the advantages and disadvantages of federal reuse regulations on the future application of water reuse to address the nation's water needs while appropriately protecting public health.

#### Regulations for Potable Reuse

There is no evidence that the current regulatory framework fails to protect public health when planned or de facto reuse occurs; however, federal efforts to address potential exposure to wastewater contaminants will become increasingly important as water reuse accounts for a larger share of potable supplies. The Safe Drinking Water Act does not include specific requirements for treatment or monitoring when municipal wastewater effluent is an important component of source water. Presently, many potable reuse projects include additional controls such as advanced treatment and increased monitoring in response to concerns raised by state or local regulators or the recommendations of expert



**Figure 2.** Relative risk of illness (gastroenteritis) to persons drinking water from two different reuse scenarios relative to de facto reuse (Scenario 1; 5% secondary effluent in a surface water source for a conventional drinking water treatment plant). In Scenario 2, treated wastewater is allowed to filter slowly through surface soils into an aquifer before reuse. In Scenario 3, wastewater is treated with advanced treatment techniques including microfiltration, reverse osmosis, advanced oxidation, and groundwater recharge before reuse. The smaller the number, the lower the relative risk for each organism. For example in Scenario 2, the risk of illness due to salmonella is estimated to be less than 1/100th of the risk to salmonella in scenario 1. The risk for salmonella and cryptosporidium in Scenario 3 were below the limits that could be assessed by the model, indicated by \*.

advisory panels. Adjustment of the Safe Drinking Water Act to consider such treatment or monitoring requirements for planned or de facto water reuse could help achieve reliable public health protection that is consistent nationwide. This would also enhance public confidence in the safety of potable reuse.

### Research Needs

The committee identified 14 water reuse research priorities in the areas of health, social, and environmental issues, and performance and quality assurance. These research priorities have the potential to advance the safe, reliable, and cost-effective reuse of municipal wastewater where traditional sources are inadequate.

## *Water Reuse-Related Research Needs*

### **Health, Social, and Environmental Issues**

1. Quantify the extent of de facto potable reuse in the United States.
2. Address critical gaps in the understanding of health impacts of human exposure to constituents in reclaimed water.
3. Enhance methods for assessing the human health effects of chemical mixtures and unknowns
4. Strengthen waterborne disease surveillance, investigation methods, governmental response infrastructure, and epidemiologic research tools and capacity
5. Assess the potential impacts of environmental applications of reclaimed water in sensitive ecological communities.
6. Quantify the non-monetized costs and benefits of potable and nonpotable water reuse compared to other water supply sources to enhance water management decision making.
7. Examine the public acceptability of engineered multiple barriers compared to environmental buffers for potable reuse.

### **Treatment Efficiency and Quality Assurance**

8. Develop a better understanding of contaminant attenuation in environmental buffers.
9. Develop a better understanding of the formation of hazardous transformation products during water treatment for reuse and ways to minimize or remove them.
10. Develop a better understanding of pathogen removal efficiencies and the variability of performance in various unit processes and multibarrier treatment and develop ways to optimize these processes.
11. Quantify the relationships between organisms detected (using the polymerase chain reaction (PCR)) and viable organisms in samples at intermediate and final stages of treatment.
12. Develop improved techniques and data to consider hazardous events or system failures in risk assessment of water reuse.
13. Identify better indicators and surrogates that can be used to monitor process performance and develop online real-time or near real-time analytical monitoring techniques for their measurement.
14. Analyze the need for new reuse approaches and technology in future water management.

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The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Environmental Protection Agency, U.S. Bureau of Reclamation, National Science Foundation, National Water Research Institute, Centers for Disease Control and Prevention, Water Research Foundation, Orange County Water District, Orange County Sanitation District, Los Angeles Department of Water and Power, Irvine Ranch Water District, West Basin Water District, Inland Empire Utilities Agency, Metropolitan Water District of Southern California, Los Angeles County Sanitation Districts, and Monterey Regional Water Pollution Control Agency. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.



For more information, contact the Water Science and Technology Board at (202) 334-3422 or visit <http://dels.nas.edu/wstb>. Copies of *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; [www.nap.edu](http://www.nap.edu).

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