

U.S. Wastewater Treatment

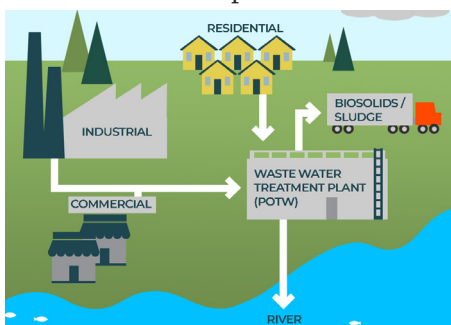
Patterns of Use

Wastewater treatment protects human and ecological health from waterborne diseases and pollutants such as excess nutrients.¹ Since 1972, effluent water quality has improved at Publicly Owned Treatment Works (POTWs) and other point source discharges through major public and private investments prescribed by the Clean Water Act.^{2,3} Despite improved effluent quality, discharges continue to contribute to surface water quality degradation.¹ Much existing wastewater infrastructure—collection systems, treatment plants, and equipment—is aging or outdated and needs repair or replacement.

Contamination and Impacts

- Pollutants contaminate receiving waters through multiple point source¹ and non-point source¹ (air deposition, agriculture) pathways including: combined sewer overflows (CSOs),⁵ sanitary sewer overflows (SSOs),⁶ stormwater runoff,⁷ and hydrologic modifications (channelization and dredging).⁸
- CSOs are treated or untreated discharges from older combined systems designed to carry both stormwater and sewage. SSOs are untreated sewage discharges from separate collection systems.^{9,10}
- CSO discharges have decreased over time.^{11,12} 8.8B gal of untreated wastewater were discharged into Michigan waterways from CSOs in 2021, down from 25B gal in 2011.⁹
- Inflow and infiltration (I/I) are unintended water entries into sewer systems from surface water sources like rivers and springs and from groundwater through cracks in pipes.¹¹ I/I can account for up to 50% of total sewer system flow, using valuable capacity and causing more frequent overflows.¹³
- In the U.S., 58% of river and stream miles, 40% of lake acres, 17% of estuarine square miles, and 23% of Great Lakes shoreline miles assessed by the U.S. EPA have excess nutrients.¹⁵ These come from agriculture, urban runoff, and wastewater treatment, causing water quality problems, such as algal blooms and fish mortality.¹⁵

Municipal Wastewater Transport¹⁴

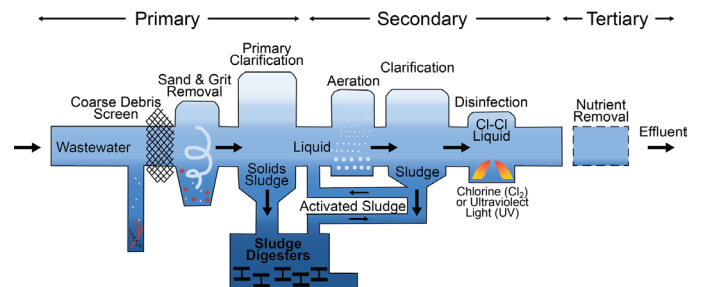


- Around 19% of households are not served by public sewers and depend on septic systems,¹⁶ discharging over 4B gal of wastewater below ground every day.¹⁷ Failing septic systems may contaminate surface and groundwater.¹⁸

Treatment of Municipal Wastewater

- A common component of wastewater treatment is activated sludge, an aerobic process that exposes microbes to oxygen to break down organic waste.¹⁹
- Over 17,000 POTWs treat and discharge over 34B gal/d of wastewater into U.S. waterways.^{20,21} 1.9M mi of piping provide collection, treatment, and disposal services to more than 270M people.^{20,22}
- Use of reclaimed water for consumption is becoming more common, particularly in drought-prone regions or areas with growing water demand (such as the U.S. southwest).²³
- POTWs generate over 13.8M tons (dry weight) of sludge (biosolids) annually.²¹ Sludge treatment accounts for one-third of POTW electricity use.²⁴
- Chlorination is the most common disinfection method in the U.S., often followed by dechlorination to avoid ecological impacts and carcinogenic by-product formation.^{25,26,27} Ultraviolet (UV) disinfection and ozonation are alternatives with higher maintenance, energy, and capital costs that are highly effective against microorganisms.^{27,28}

Wastewater Treatment Process²⁹

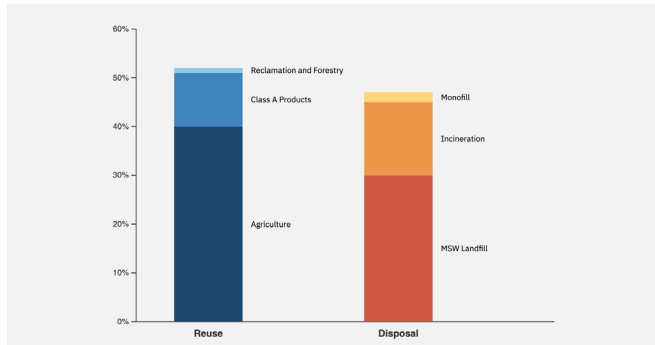


- Contaminants of emerging concern (CEC) are unregulated compounds found in many products.³⁰ Per- and polyfluoroalkyl substances (PFAS) and polybrominated diphenyl ethers (PBDE) have become CECs due to their wide distribution and persistence in the environment.³¹ Some of these chemicals are endocrine disruptors and affect growth and reproduction.³² Many of these chemicals are not removed by POTWs.³³ Researchers are currently studying technologies for removing PFAS from drinking and wastewater.³⁴

Biosolids End-of-Life

- Biosolids are nutrient-rich treated sludge resulting from POTW treatment of municipal wastewater.³⁵
- U.S. management practices result in 60% of biosolids being used for land applications (agricultural, home garden, landscaping), with minor amounts applied to forests and reclamation sites, while 38% are landfilled or incinerated.²

Biosolid Use³⁶



Lifecycle Impacts

Wastewater treatment systems reduce environmental impacts in receiving waters but create other life cycle impacts, mainly through energy use. GHG emissions are associated with energy and chemicals used in treatment and with the degradation of organic materials in POTWs.

Electricity Consumption and Emissions

- About 2% of U.S. electricity use goes towards pumping and treating water and wastewater.²⁴
- In 2022, energy-related emissions resulting from POTW operations, excluding organic sludge degradation, were 10.5 Tg CO₂e, 4.92 Gg SO₂, and 6.19 Gg NO_x.^{24,27}
- An estimated 20.8 and 21.9 Mt CO₂e of CH₄ and N₂O, respectively, resulted from wastewater treatment processes in 2022, about 0.7% of U.S. GHG emissions.³⁸

Social and Economic Impacts

- In the U.S., an average household pays \$780 annually for wastewater collection and treatment, an 85% increase from 2010.²²
- Although sewer systems last longer (50 years) than treatment equipment (15-20 years), sewer renovation can be costly.³⁹
- Nationwide costs for infrastructure to meet identified clean water needs total \$630B through 2041. 55% of these needs are for wastewater infrastructure: treatment plant improvements, conveyance systems (new and repair), CSO correction, recycled water distribution, and desalination.²⁰
- The federal government's share of wastewater capital investment fell from 63% in 1977 to 9% in 2017.³

Solutions and Sustainable Actions

Administrative Strategy

- Investment in wastewater treatment is shifting from new construction to asset management—maintaining original capacity and function. Life cycle costing should be embedded in capital budgeting, and programs for CSO, SSO, and stormwater asset management need to be permanent.⁴⁰

- To meet ambient water quality standards, total maximum daily loads (TMDLs) including both point and non-point source pollutant loadings can be developed.⁴¹
- Federal and state governments have developed strategies to remove emerging pollutants like PFAS from point sources by requiring POTWs and industries to sample for emerging pollutants, enabling source identification and correction.¹⁴
- Since 2021, federal funding has increased significantly through the Infrastructure Investment and Jobs Act, providing an additional \$11.7B to the water sector (drinking water, wastewater, stormwater).²²
- The Water Infrastructure Finance and Innovation Act (WIFIA) program funding also increased from \$69.5M in FY22 to \$72.3M in FY24 for large multisector infrastructure projects.²²

Reduce Loading

- Projects to reduce or divert wastewater flow include disconnecting household rainwater drainage from sanitary sewers, installing green roofs, and replacing impervious surfaces with porous pavement, swales, or French drains.
- Toilets, showers, and faucets represent 64% of indoor water use. Install high-efficiency toilets, composting toilets, low-flow shower heads, faucet aerators, and rain barrels.⁴² Efficient appliances have contributed to a 22% decline in household water use since 1999.⁴²

Technology Improvements and System Design

- Aeration, which facilitates microbial degradation of organic matter, can account for 25-60% of wastewater treatment plant energy use. Flexible designs allow systems to meet fluctuating oxygen demands by time of day and season.⁴³ Pumping systems use 10-15% of treatment plant energy and this demand can be reduced when pumps, flow control, and motors are matched to plant needs.²⁴
- A number of treatment plants are considering using methane from anaerobic digestion of biosolids as an energy resource.²⁴
- Water reuse can significantly decrease system energy use and reduce nutrient loads to receiving waters.⁴⁴
- Large-scale urine diversion could decrease nutrient loading in wastewater treatment plants and lead to reductions of up to 47% in GHG emissions and 41% in energy use.⁴⁵

Great Lakes Water Authority (Detroit POTW)⁴⁶

