A Section 508–conformant HTML version of this article
is available at https://doi.org/10.1289/EHP15000.

Invited Perspective: Toward Resilience—Community-Based Approaches to Managing Combined Sewer Overflows in a Changing Climate

Jan C. Semenza[1,2]

[1]Department of Public Health and Clinical Medicine, Umeå University, Umeå, Sweden
[2]Heidelberg Institute of Global Health, University of Heidelberg, Heidelberg, Germany

https://doi.org/10.1289/EHP15000

Refers to https://doi.org/10.1289/EHP14213

The hydrologic cycle—the perpetual movement of water across the earth—accelerates under the influence of climate change, which enhances extreme rainfall.[1] This escalation lays bare structural vulnerabilities inherent within the fabric of our infrastructure. Particularly susceptible to disruption is the collection of wastewaters from residential and commercial entities, especially in urban areas when combined with runoff from impermeable surfaces. If the sanitary sewer network is combined with storm sewers carrying urban drainage, it can become overloaded as it transports wastewater to the treatment plant. Equipped with release valves, these combined sewer systems release untreated stormwater and wastewater into nearby waterbodies if the amount of runoff exceeds the capacity of the system—an event termed a combined sewer overflow (CSO).[1] While serving to avert overloading of treatment facilities and prevent inundation of buildings with wastewater, CSOs result in the discharge of effluents into the environment.

In the United States, ∼700 communities—predominantly clustered in the Northeast and around the Great Lakes, reflecting an older solution to wastewater management—have combined sewer systems and periodically experience CSO discharges (Figure 1). These events are of concern given that they can contaminate surface waterbodies with pathogens and carry them to drinking water sources downstream.[1] Microbes discharged in wastewater during CSO incidents include bacteria, such as *Campylobacter, Salmonella* sp., *Streptococcus* sp., and *Enterococcus* sp.[2,3]; protozoan parasites, such as *Giardia* and *Cryptosporidium*[4]; and viruses, such as norovirus, hepatitis A and E viruses, and adenovirus.[5] In communities where a CSO discharges directly into a drinking water source, there is an increased risk of emergency department visits for gastrointestinal illness, especially following bouts of extreme precipitation.[6]

In a new study in this issue of *Environmental Health Perspectives*, Haley et al. examined the relationship between CSO discharge volume and emergency department visits for acute gastrointestinal illness, after adjusting for precipitation.[7] Extreme CSO events were associated with a 22% increase in risk for these health outcomes.[7] Notably, these risks persisted irrespective of the source of drinking water, indicating additional exposure pathways beyond contaminated drinking water. Releasing wastewater with microbial hazards into the environment poses a risk not only to the drinking water supply but also to beaches, freshwater ecosystems, and shellfish aquaculture.[8–10]

For example, discharging untreated urban runoff onto public beaches during extreme rain events exacerbates the risk of gastrointestinal illness from recreational water use.[11] I clearly remember the enormous plumes of contaminated effluent at the river mouth on the beaches of Southern California, particularly after the rain during an El Niño year. Surfers exposed to these contaminated waters suffered not only from gastrointestinal diseases but also from skin and eye infections, as well as significant respiratory disease, with symptoms such as fever, sinus problems, sore throat, cough, and phlegm.[11] A study of the general beachgoing public in the same area showed they suffered from a high incidence of gastroenteritis during the winter months—when the rain flushed urban runoff into the coastal waters—compared with the summer.[12] The economic burden associated with infectious diseases due to recreational water use at polluted coastal waters is substantial and justifies remediation.[13]

However, microbiological contaminants represent merely one facet of the hazard associated with CSOs; chemicals in domestic wastewater compound the potential environmental risks. These contaminants include triclosan from shampoos, soaps, and toothpastes[14]; pharmaceuticals, such as erythromycin, fluoxetine, and diclofenac[15]; per- and polyfluoroalkyl substances[16]; diethylhexyl phthalate leaching from polyvinyl chloride piping[17]; and pesticides and nutrients from agricultural and gardening activities.[18] Wastewaters from urban, rural, and industrial sources differ in their composition and are of concern for acute vs. chronic health effects depending on their source.[19]

Climate change is a risk multiplier for many environmental hazards, and CSOs are no exception. Ensuring access to safe drinking water remains a cornerstone of public health practice, particularly in the face of evolving climatic conditions.[20] However, remediating these multifaceted risks to public health and the environment presents formidable challenges. Overhauling an aging infrastructure is obviously resource intensive. Besides retrofitting outdated modes of wastewater management, it also entails source reduction (i.e., limiting water use), reuse of gray water, and redirection of storm runoff.[20]

The US Environmental Protection Agency proposes a suite of alternative approaches for communities to use in managing stormwater.[21] For example, green infrastructure entails nature-based solutions, such as percolation ponds, which are designed to collect, store, and filter stormwater into the aquifer to reduce flood incidence. Gray infrastructure involves engineered structures that collect water during times of high wastewater load and alleviate pressure on the water treatment plant. Integrated planning involves a community-based prioritization process that seeks to address those issues with the greatest human health and environmental consequences. Smart data infrastructure focuses on the collection, storage, and analysis of water-related data. And finally, real-time meteorological monitoring serves as an early warning system, enabling proactive decision-making and timely alerts to the

Address correspondence to Jan C. Semenza. Telephone: 46-76-101-0711. Email: Jan.Semenza@lateralPHC.com

The author declares he has no competing interests related to this work to disclose.

Conclusions and opinions are those of the individual authors and do not necessarily reflect the policies or views of EHP Publishing or the National Institute of Environmental Health Sciences.

Received 18 March 2024; Accepted 16 April 2024; Published 22 May 2024.

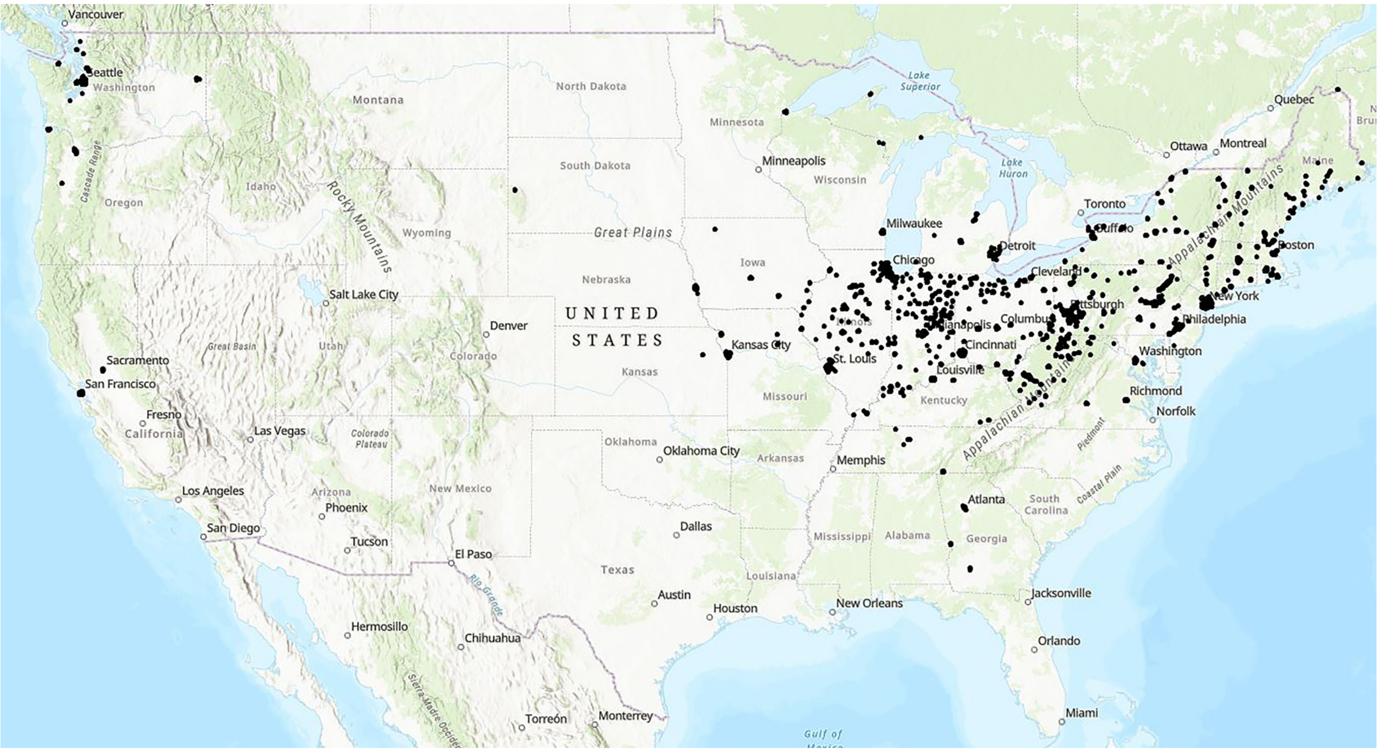

Figure 1. Combined sewer overflow outfalls, United States, 2024.[21] Based on data from the National Combined Sewer Overflow Inventory, updated weekly. Source: US Environmental Protection Agency, 2024.

community regarding compromised waterbodies. When comparing green and gray infrastructure projects, the former may be preferable because they can have socioeconomic, environmental, and community benefits, such as restoration of biodiversity and ecosystem services; increased real estate values; opportunities for increased tourism and leisure activity; and improved public health.[18] Gray infrastructure projects, on the other hand, while effective, are encumbered by high costs and carbon footprints.[18] Embracing green and community-centered approaches not only safeguards public health but also advances systemic resilience to climate change.[22]

References

1. Semenza JC. 2020. Cascading risks of waterborne diseases from climate change. Nat Immunol 21(5):484–487, PMID: 32313241, https://doi.org/10.1038/s41590-020-0631-7.
2. McGinnis S, Spencer S, Firnstahl A, Stokdyk J, Borchardt M, McCarthy DT, et al. 2018. Human *Bacteroides* and total coliforms as indicators of recent combined sewer overflows and rain events in urban creeks. Sci Total Environ 630:967–976, PMID: 29554782, https://doi.org/10.1016/j.scitotenv.2018.02.108.
3. Tondera K, Klaer K, Gebhardt J, Wingender J, Koch C, Horstkott M, et al. 2015. Reducing pathogens in combined sewer overflows using ozonation or UV irradiation. Int J Hyg Environ Health 218(8):731–741, PMID: 26431869, https://doi.org/10.1016/j.ijheh.2015.09.002.
4. Donovan E, Unice K, Roberts JD, Harris M, Finley B. 2008. Risk of gastrointestinal disease associated with exposure to pathogens in the water of the Lower Passaic River. Appl Environ Microbiol 74(4):994–1003, PMID: 18156342, https://doi.org/10.1128/AEM.00601-07.
5. Robins PE, Farkas K, Cooper D, Malham SK, Jones DL. 2019. Viral dispersal in the coastal zone: a method to quantify water quality risk. Environ Int 126:430–442, PMID: 30836310, https://doi.org/10.1016/j.envint.2019.02.042.
6. Jagai JS, Li Q, Wang S, Messier KP, Wade TJ, Hilborn ED. 2015. Extreme precipitation and emergency room visits for gastrointestinal illness in areas with and without combined sewer systems: an analysis of Massachusetts data, 2003–2007. Environ Health Perspect 123(9):873–879, PMID: 25855939, https://doi.org/10.1289/ehp.1408971.
7. Haley BM, Sun Y, Jagai JS, Leibler JH, Fulweiler R, Ashmore J, et al. 2024. Association between combined sewer overflow events and gastrointestinal illness in Massachusetts municipalities with and without river-sourced drinking water, 2014–2019. Environ Health Perspect 132(5):057008, https://doi.org/10.1289/EHP14213.
8. McLellan SL, Hollis EJ, Depas MM, Van Dyke M, Harris J, Scopel CO. 2007. Distribution and fate of *Escherichia coli* in Lake Michigan following contamination with urban stormwater and combined sewer overflows. J Great Lakes Res 33(3):566–580, https://doi.org/10.3394/0380-1330(2007)33%5B566:DAFOEC%5D2.0.CO;2.
9. Semenza JC, Caplan JS, Buescher G, Das T, Brinks MV, Gershunov A. 2012. Climate change and microbiological water quality at California beaches. Ecohealth 9(3):293–297, PMID: 22805768, https://doi.org/10.1007/s10393-012-0779-1.
10. Patz JA, Vavrus SJ, Uejio CK, McLellan SL. 2008. Climate change and waterborne disease risk in the Great Lakes region of the U.S. Am J Prev Med 35(5):451–458, PMID: 18929971, https://doi.org/10.1016/j.amepre.2008.08.026.
11. Dwight RH, Baker DB, Semenza JC, Olson BH. 2004. Health effects associated with recreational coastal water use: urban versus rural California. Am J Public Health 94(4):565–567, PMID: 15054006, https://doi.org/10.2105/ajph.94.4.565.
12. Brinks MV, Dwight RH, Osgood ND, Sharavanakumar G, Turbow DJ, El-Gohary M, et al. 2008. Health risk of bathing in Southern California coastal waters. Arch Environ Occup Health 63(3):123–135, PMID: 18980875, https://doi.org/10.3200/AEOH.63.3.123-135.
13. Dwight RH, Fernandez LM, Baker DB, Semenza JC, Olson BH. 2005. Estimating the economic burden from illnesses associated with recreational coastal water pollution—a case study in Orange County, California. J Environ Manage 76(2):95–103, PMID: 15939121, https://doi.org/10.1016/j.jenvman.2004.11.017.
14. Guerra P, Teslic S, Shah A, Albert A, Gewurtz SB, Smyth SA. 2019. Occurrence and removal of triclosan in Canadian wastewater systems. Environ Sci Pollut Res Int 26(31):31873–31886, PMID: 31489545, https://doi.org/10.1007/s11356-019-06338-w.
15. Gardner M, Jones V, Comber S, Scrimshaw MD, Coello-Garcia T, Cartmell E, et al. 2013. Performance of UK wastewater treatment works with respect to trace contaminants. Sci Total Environ 456–457:359–369, PMID: 23624009, https://doi.org/10.1016/j.scitotenv.2013.03.088.
16. Behnami A, Benis KZ, Pourakbar M, Yeganeh M, Esrafili A, Gholami M. 2024. Biosolids, an important route for transporting poly-and perfluoroalkyl substances from wastewater treatment plants into the environment: a systematic review. Sci Total Environ 925:171559, PMID: 38458438, https://doi.org/10.1016/j.scitotenv.2024.171559.

17. Rule KL, Comber SD, Ross D, Thornton A, Makropoulos CK, Rautiu R. 2006. Sources of priority substances entering an urban wastewater catchment—trace organic chemicals. Chemosphere 63(4):581–591, PMID: 16216304, https://doi.org/10.1016/j.chemosphere.2005.08.016.
18. Perry WB, Ahmadian R, Munday M, Jones O, Ormerod SJ, Durance I. 2023. Addressing the challenges of combined sewer overflows. Environ Pollut 343:123225, PMID: 38151091, https://doi.org/10.1016/j.envpol.2023.123225.
19. Nickel JP, Fuchs S. 2019. Micropollutant emissions from combined sewer overflows. Water Sci Technol 80(11):2179–2190, PMID: 32198335, https://doi.org/10.2166/wst.2020.035.
20. Semenza JC, Ko AI. 2023. Waterborne diseases that are sensitive to climate variability and climate change. N Engl J Med 389(23):2175–2187, PMID: 38055254, https://doi.org/10.1056/NEJMra2300794.
21. US EPA (US Environmental Protection Agency). 2023. Combined Sewer Overflow Solutions—Management Approaches. [Website.] Updated 5 October 2023. https://www.epa.gov/npdes/combined-sewer-overflow-solutions-management-approaches [accessed 18 March 2024].
22. Semenza JC. 2021. Lateral public health: advancing systemic resilience to climate change. Lancet Reg Health Eur 9:100231, PMID: 34642677, https://doi.org/10.1016/j.lanepe.2021.100231.