Resident perspectives of top-down, municipal-scale, streetside bioretention in China, Sweden, and USA

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Highlights

- Survey exploring reasons residents support or oppose bioretention implemented on 3 continents
- Identified multifaceted influences shaping resident perceptions of streetside bioretention
- Aiming to synthesize findings to provide tailored recommendations for stormwater professionals

Introduction

As urbanization accelerates globally, drainage problems like flooding and poor water quality challenge cities and downstream ecosystems. Bioretention is one of many nature-based solutions to these problems, using soil and plants to absorb and filter stormwater runoff, restoring natural hydrological processes, and fostering urban resilience. Given that residents interact and engage with municipal-scale, streetside bioretention daily, securing public acceptance becomes critical for its successful integration as a stormwater treatment solution worldwide. In some cases, bioretention is celebrated for its multifaceted benefits and often a positive public perception is taken for granted. However, residents may also oppose and even protest these top-down, streetside bioretention projects (Figure 1). Understanding divergent perspectives requires situating bioretention within a larger context as part of a social-ecological-technical system.

We aim to address these perspectives by: 1) developing a theory-based survey to explore factors contributing to resident views of streetside bioretention across societies and demographic characteristics, 2) investigating the multifaceted factors influencing resident perspectives of bioretention, and 3) synthesizing results to provide actionable recommendations for policymakers, planners, engineers, and public outreach strategists.

Methodology

Theory exploration

We formed an interdisciplinary team of natural and social scientists from China, Sweden, and the USA. To guide our investigation we used three theoretical frameworks: social-ecological-technical systems, ecosystem services, and collective action.

Figure 1. Columbus, OH residents oppose rain gardens (bioretention) via social media (Facebook, 2017)

Survey development

Our survey targeted residents with top-down, municipal-scale bioretention projects, including Wuhan, China, a 2015 pilot Sponge City initiated by the national government, and Columbus, Ohio, USA, responding to state government mandates to abate sanitary sewer overflows with Blueprint Columbus. Given Sweden's small population size, less than that of the city of Wuhan, we targeted residents of multiple Swedish municipalities with bioretention installations in either existing areas or new developments. Gender and age quotas were aligned with the demographic distribution of each surveyed population. Administered through a company, Qualtrics, to minimize snowball effects and biases, the 10-minute survey aimed for 900 responses (300 per national context) and was comprised of six sections. The first section focused on respondents' experiences with bioretention, featuring nine images (Figure 2). AI was used to clear images of national context indicators (e.g. road signs, cars, etc.). Respondents selected and commented on reasons for their most and least preferred bioretention, offering both quantitative and qualitative insights.

Figure 2. The nine bioretention images shown to respondents. Flags of countries were not shown to respondents but indicate the place where the image was taken – China (a, d, g), Sweden (b, e, h), and the USA (c, f, i). Green or red text describes the three most- and least-preferred bioretention designs per national context. Since respondents were asked to choose their most- and least-preferred bioretention image instead of ranking, it was possible for one image to be among both the most- and least-preferred (b, e). China responses not yet available.

Key Findings

As of March 2023, we are still awaiting complete Chinese responses. Overall, residents' highest priority for bioretention was benefiting the ecosystem and flood prevention, while the least emphasis was placed on providing recreational spaces. Our results indicate that support for and experience with bioretention can vary by cultural context. Across different countries, residents demonstrate varying degrees of familiarity, acceptance, and reservations toward bioretention, highlighting the impact of cultural nuances and municipal implementation on shaping attitudes (Guo et al., 2022). Notably, in all three national contexts, respondents predominantly favored a bioretention design from a different national context, indicating the potential for global sharing and adoption of design ideas between municipalities worldwide.

Recommendations

Residents and their perspectives should be considered during all stages of bioretention planning. This enabled a deeper investigation into the diverse factors influencing residents' perspectives of bioretention. Our ongoing work anticipate providing nuanced insights and tailored recommendations for policymakers, planners, engineers, and public outreach strategists, fostering broader acceptance and successful integration of bioretention as a versatile stormwater treatment solution worldwide.

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Trendspotting: Assessing the First 10 Years of GSI Infiltration Performance in Philadelphia

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Highlights

- 11 years of monitoring data from subsurface GSI were used to understand decreasing infiltration rates in the bottom footprint due to sediment accumulation.
- Bottom infiltration service life (BISL), an estimate of the time for infiltration out of the bottom 6 inches of storage to reach 0 in/hr, was calculated with a median of 29 years and a mean of 44 years.
- BISL estimates are considered conservative because of the assumption of a linear degradation trend.

Introduction

The Philadelphia Water Department (PWD) is approaching the halfway point of *Green City, Clean Waters*, the city's 25-year long program to reduce combined sewer overflows through the construction of green stormwater infrastructure (GSI). *Green City, Clean Waters* uses an adaptive management approach to reaching its goal of 85% pollution reduction by the year 2035. Adaptive management requires evaluation of cost-alternatives at 5-year milestones of the program. As the 15-year milestone approaches, there is a need to reassess many of the factors used in the initial cost-alternatives analysis. Of these assumptions, the service life of GSI stands out as an important leverage point in analysis without an industry defined standard. An initial estimate of 25-years for subsurface infiltration GSI was used in the analysis that led to the creation of *Green City, Clean Waters*. This value was based on a literature review completed by ECONorthwest in 2007. In the intervening years since the beginning of the program, both the industry of GSI and PWD have made progress in refining design standards beyond those used in 2012. During this time, PWD has also constructed over 1,200 public GSI systems, equivalent to stormwater management practices (SMPs). A portion of these monitored SMPs were selected for long-term continuous monitoring. Data from these long-term monitored SMPs were used to help inform infiltration GSI service life assumptions.

Methodology

Typical monitoring for an SMP consists of a site inspection followed by the deployment of an Onset HOBO pressure transducer into an observation well to record water level readings in the subsurface stone of an SMP. These pressure data are locally stored on the sensors, which are routinely retrieved by field personnel. The data are then subjected to quality assurance and control procedures before being entered into a postgreSQL database for post-processing. During quality assurance, raw pressure readings are converted based on a network of barometric pressure sensors into water level measurements. Analyses on these water level data are then performed through a series of R scripts and functions. The water level measurements are then associated with storm events based on datetimes with storm events being defined by an interevent time of 6-hours. The draindown time for the final six inches of water for each storm is used to calculate the infiltration rate for each storm event.

SMPs determined to have a significant length of monitoring time and consistent infiltration rate results were chosen for further analysis. Infiltration rates were assessed for monotonic changes over time to determine when an SMP would cease to infiltrate in the bottom six inches of the subsurface stone. Seasonal changes were accounted for through a regression of infiltration rate with respect to the mean water temperature for each storm event. The residuals of this regression were then passed through a Mann-Kendall test to determine the strength of any monotonic changes observed. A Theil-Sen slope was then calculated to determine the magnitude of change in infiltration rate over time for each of the SMPs evaluated. Using these Theil-Sen slopes, construction dates, and a mean infiltration rate, the estimated time to failure was calculated for each SMP. Estimated failure time for one of these SMPs was compared against a simulated runoff test (SRT) to compare expected infiltration rates from calculations against real world observations. Bootstrapping was then used to extrapolate these estimates out to the wider population of subsurface infiltration SMPs.

Key Findings

15 SMPs were identified as having a negative monotonic trend after removing seasonality. Theil-sen slopes were used to predict the average change in infiltration year over year. Using these slopes and mean starting infiltration rates, the BISL was estimated for each SMP before they are converted to slow-release (see Figure 1). BISL across all 15 SMPs has a median of 29 years and a mean of 43.86 years with a 95% confidence range of +/- 17.65 years. One of these 15 SMPs, 20-4-1, was predicted to already have clogged in the bottom six inches of stone based on the Theil-Sen slope. When performing a simulated runoff test (SRT) at this system, it was found to still be infiltrating in the bottom six inches of stone at a rate of 0.12 in/per.

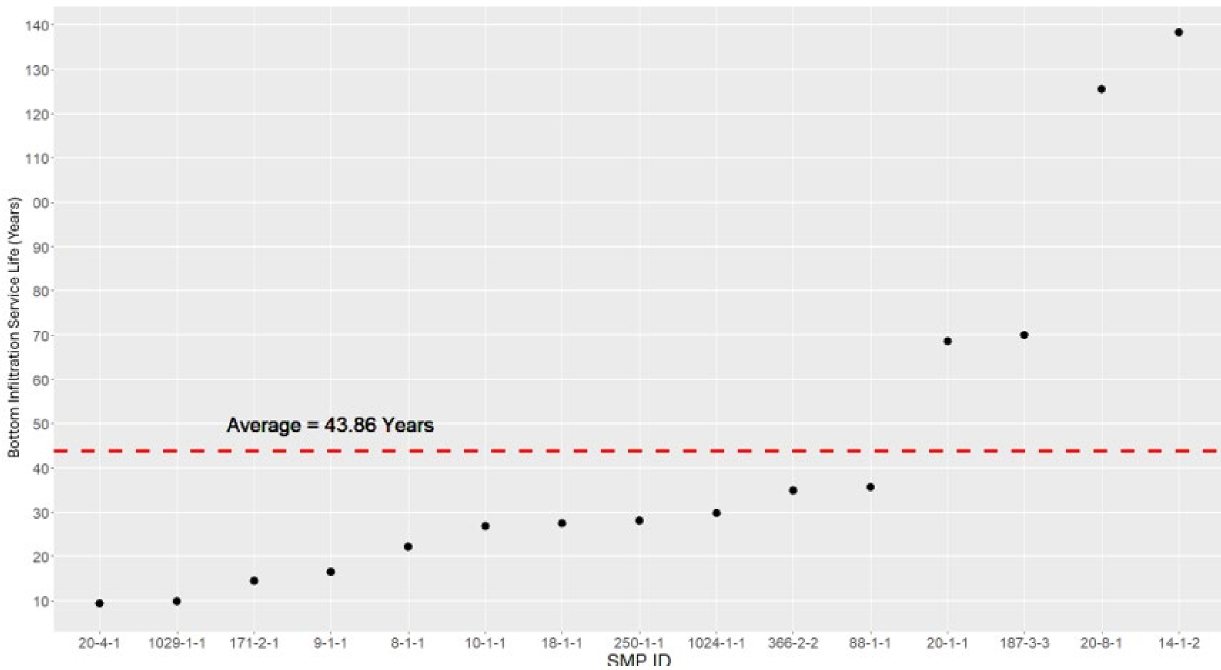

Figure 1. Bottom Infiltration Service Life (Years) for the 15 SMPs analyzed

Recommendations

The BISL offers an important but incomplete view of an SMPs service life for other municipalities and utilities to consider; however, the predictions shown are with limitations and their shortcomings should be noted. These limitations include non-random sampling, a biased towards an older generation of GSI design, and assumptions of linear infiltration rate decrease. An expanded sampling and monitoring plan with the intent to improve the accuracy of and confidence in estimating infiltration rate degradation will be presented.

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Clean Water Act Compliance During Wet Weather: Lessons and Recommendations

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Highlights

- Many of the nation's water bodies remain impaired, particularly during wet weather conditions.
- This WRF project evaluated permitting approaches and compliance tools for wet weather conditions.
- Recommendations to improve CWA regulatory programs and water quality for wet weather discharges.

Introduction

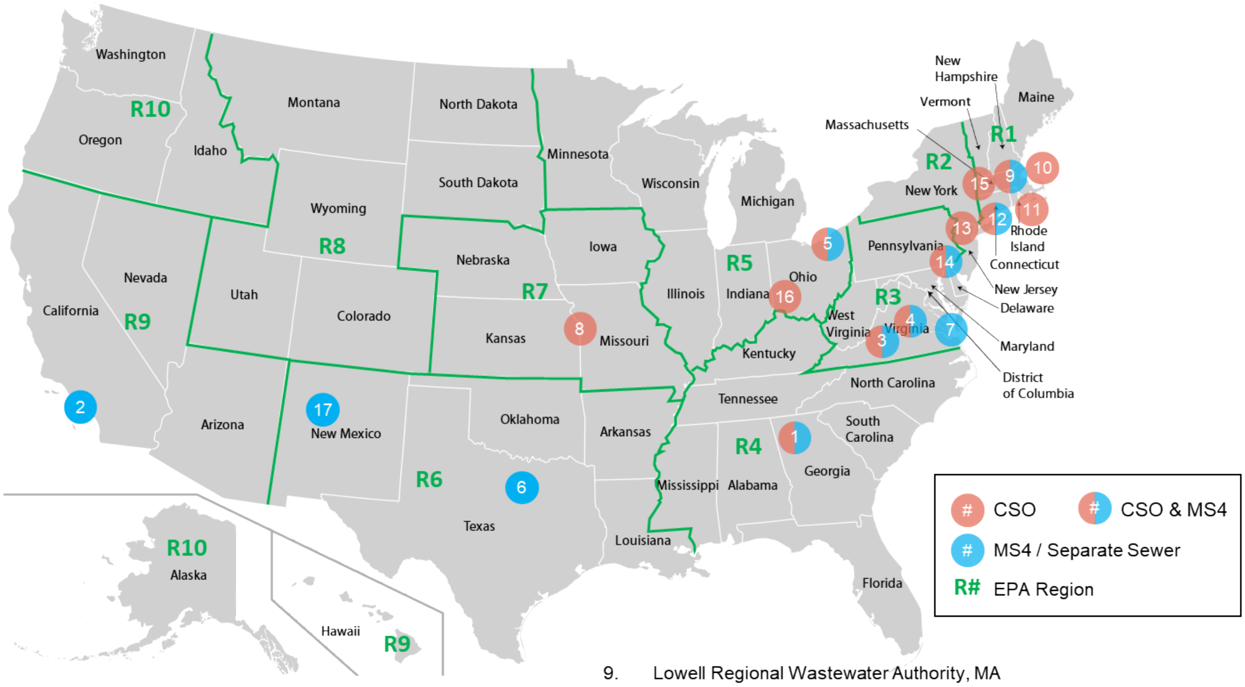
The Clean Water Act's (CWA's) focus on point source discharges has brought about significant improvements in water quality, but many of the nation's water bodies remain impaired, particularly during wet weather conditions. In recent years, there is a push for increasingly stringent regulation of stormwater discharges, combined sewer overflows (CSOs), and nonpoint sources (such as agriculture). However, it is not clear that traditional regulatory approaches are technically suitable for wet weather flows, or that they represent the best way to achieve significant water quality improvements.

Background

This presentation summarizes the findings from a recent Water Research Foundation (WRF) project (final report is to be published in late 2024). The objective of the study was to evaluate current permitting approaches and compliance tools for wet weather conditions and to provide recommendations for regulatory agencies and permittees to improve CWA regulatory programs and water quality outcomes for wet weather discharges.

Key Findings

Partnering with 17 utilities across the nation and academic advisors (see Figure 1), the study confirmed that wet weather regulatory programs are challenging to develop and implement because of the unique and highly variable conditions that occur during wet weather events. Permittees are concerned about requirements they perceive to be stringent and inflexible, leading to a focus on permit compliance rather than improved water quality outcomes—concerns that may be exacerbated by future requirements to address climate change, constituents of emerging concern (such as PFAS), and measures of receiving water quality (such as biological objectives).



1. City of Atlanta, GA
2. City of Los Angeles /LASAN, CA
3. City of Lynchburg Water Resources, VA
4. City of Richmond Public Utilities, VA
5. City of Solon, OH
6. Dallas Fort Worth International Airport, TX
7. Hampton Roads Sanitation District, VA
8. Kansas City Water, MO
9. Lowell Regional Wastewater Authority, MA
10. Massachusetts Water Resource Authority, MA
11. Narragansett Bay Commission, RI
12. New York City DEP, NY
13. Passaic Valley Sewerage Commission, NJ
14. Philadelphia Water Department, PA
15. Springfield Water and Sewer Commission, MA
16. Metropolitan Sewer District of Greater Cincinnati, OH
17. Albuquerque Metropolitan Arroyo Flood Control Authority, NM

Figure 1. Participating Utilities Members

The study shows that regulatory agencies have attempted to address these concerns by working with permittees to modify water quality standards (e.g., to suspend recreational uses during high flows, develop site-specific objectives for metals, or eliminate permit requirements not supported by science). Wet weather permit approaches identified in the study include watershed management programs, trading, variances, compliance schedules, multiple pathways to demonstrate compliance, and integrated permits that combine wastewater and stormwater obligation. While helpful, these approaches do not address comprehensive concerns about CWA implementation during wet weather.

Recommendations

The study recommends that EPA invest in and develop guidance for CWA programs, including evaluating water quality standards and how to translate the frequency, magnitude, and duration aspects of water quality standards for wet weather discharges. Guidance is needed regarding the use of Financial Capability Assessments (FCAs) to prioritize permit implementation over time and enable use of sustainable, nature-based solutions. Dedicated funding sources and research into the efficacy of treatment technologies for wet weather conditions are critical. Finally, guidance will be needed regarding the implementation of requirements for constituents of emerging concern, climate change, and integrative water quality measures.