frontiers | Frontiers in Environmental Science

TYPE Editorial
PUBLISHED 28 November 2023
DOI 10.3389/fenvs.2023.1338537

OPEN ACCESS

EDITED AND REVIEWED BY
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RECEIVED 14 November 2023
ACCEPTED 17 November 2023
PUBLISHED 28 November 2023

CITATION
Mitchell CPJ, Oswald CJ and Ledford SH (2023), Editorial: Biogeochemical dynamics in urban systems: interactions, feedbacks and cumulative effects.
Front. Environ. Sci. 11:1338537.
doi: 10.3389/fenvs.2023.1338537

Editorial: Biogeochemical dynamics in urban systems: interactions, feedbacks and cumulative effects

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KEYWORDS

urban, biogeochemistry, hydrology, watersheds, streams, soils, contaminants, chemical cocktails

Editorial on the Research Topic
Biogeochemical dynamics in urban systems: interactions, feedbacks and cumulative effects

More than half of the world's population lives in urban areas and the proportion of urban inhabitants continues to increase in most countries (United Nations, 2019). Biogeochemical dynamics in urban systems are unique because of major alterations to hydrological dynamics and surface cover, as well as proximity to anthropogenic emissions of elements, various contaminants, greenhouse gases, and nutrients (Kaye et al., 2006). As urban areas evolve, engineered and/or nature-based solutions such as low-impact development features are also increasingly used to mitigate various impacts of urban development, but likely not yet with fully understood biogeochemical and hydrological implications (Delesantro et al., 2022; Hopkins et al., 2022; Zhang et al., 2023). Understanding the unique biogeochemical cycling dynamics in urban systems remains a major challenge to sustainable urban life and mitigation of downstream impacts.

The goal of this Research Topic was to bring diverse scientific and interdisciplinary studies, specific to biogeochemical dynamics in cities, together to advance urban biogeochemical science. Hopefully, these works can collectively help municipal decision-making that aims to improve the lives of people and organisms in cities. Biogeochemical dynamics in urban systems are largely, but not entirely, distinct from those in rural or natural landscapes. The cycling of carbon, nitrogen, phosphorus, sulfur, contaminants, and other matter in urban landscapes, water bodies, atmospheres, and green infrastructure such as green roofs continue to be re-thought, particularly in relation to demography, crumbling or renewed infrastructure, global climate change, and interactions among major environmental cycles. As the world continues to urbanize, it is increasingly clear that improving our understanding of biogeochemical dynamics in diverse urban systems at different scales is critical.

This Research Topic includes eight original research papers encompassing urban biogeochemical research across the United States, Europe, and Asia. These works have made advances in our understanding of urban salinization and solute mobility (including complex mixtures termed "chemical cocktails"), trace organic compound transformations, and the fate of metals amongst urban streams, soils and roadside dust. Several papers improved upon the understanding of biogeochemical dynamics in relation to unique urban features like buried streams, urban watershed and stream restoration infrastructure, and specific types of low-impact development.

Two of the papers (Kaushal et al.; Rossi et al.) came from large data synthesis efforts. Kaushal et al. synthesized multiple longitudinal stream synoptic monitoring data sets of water chemistry (changes in chemical concentration with increasing downstream distance) to develop a typology of water quality trends across many streams and rivers. They then examined these trends in relation to coverage of urban degraded, restored and conserved lands. The typologies observed fall into patterns characterized by increasing, decreasing, transitioning or no trends. Kaushal et al. suggest that examining the longitudinal synoptic patterns of multiple chemicals can be an informative way of investigating and quantifying how restoration and watershed management activities affect stream water quality. Rossi et al. used two decades of stream water quality data and daily flow data across six exurban and suburban watersheds to investigate relationships amongst major ion concentrations and possible controlling factors such as land-use and wastewater treatment plant discharges. They found increasing chloride, calcium, magnesium and sodium concentrations across the 20-year dataset in all six watersheds, consistent with freshwater salinization syndrome impacts on groundwater. They also found positive associations between specific ion concentrations and several landscape factors, such as impervious surface cover. Interestingly, corrosivity indices such as the Larson Index have increased by 2–7 fold over 20 years and sodium levels have risen in some waters to levels of health concern for people on low sodium diets.

Four studies (Forgrave et al.; Galella et al.; Maas et al.; Mauch et al.) examined the loading, transformation and/or attenuation, and mobility of chemicals or chemical mixtures in urban water or soil systems. In a field study, Maas et al. investigated the possibility of natural watershed attenuation of chemical cocktails, which are mixtures of multiple ions and nutrients from a common source (Kaushal et al., 2018). Maas et al. found that the attenuation and dilution of both salt ions and chemical cocktails along streams were related to riparian forest buffer width, the specific types of salt pollution and the downstream distance of the stream sampling location. Conservation and watershed restoration efforts help with attenuation and dilution at relatively low chemical concentrations, but attenuation can be overwhelmed following road salting events and when hydrological flow paths are short-circuited by storm drain infrastructure. In another field study, Forgrave et al. examined solute concentration-discharge relationships and loads from an urban buried stream impacted by sewer leaks and overflows. Using grab samples from different storms, coupled with multi-isotope approaches for tracing nitrate, Forgrave et al. pieced together a conceptual understanding of different sources of solutes (atmospheric deposition, sewer overflows and flushing of near-pipe sediment) over different timeframes of events in this unique urban watershed. In a series of laboratory experiments, Mauch et al. investigated the influence of periphyton attached to artificial substrates, invasive quagga mussels and a mixed periphyton-quagga-sediment matrix, on the transformation of three types of iodinated contrast media. Periphyton is the mixture of photo- and heterotrophic organisms attached to submerged surfaces in aquatic systems. Mauch et al. found complete or near complete reduction of concentrations of one type of contrast media, iopromide, on all the substrates, but no changes in iopamidol or diatrizoate concentrations. Mauch et al. provide possible mechanisms for periphyton facilitated iopromide transformations and suggest that increased nutrient supply from dense mussel invasions or increased surface area from dense macrophyte stands can affect iodinated contrast media transformations and therefore quality for drinking water production from urban freshwater. Galella et al. provide some links between soil systems and the mobility of complex solute mixtures (chemical cocktails). Galella et al. examined how increasing concentrations of different salts affect the mobilization of major and trace elements from soils obtained from four different stormwater management features—bioretention, bioswale, constructed wetlands and retention ponds. They found that different salt types led to the preferential mobilization of certain elements with, for example, strong co-mobilization of sodium with copper and calcium with strontium. Overall, processes such as ion exchange likely dominate the mobility of most of the elements studied since mobilization was enhanced by all types of salt addition across all types of stormwater best management features.

The final two studies in the Research Topic (Al-Taani et al.; Brewster and Bain) focus on the spatial patterning of metals in soils and dust. In a field study, Brewster and Bain examined spatial patterns of metal content in soils across six green infrastructure installations (five raingardens and one bioswale) in Pittsburgh, Pennsylvania. They found a tendency for trace metals to accumulate near roadside edges and they suggest that remobilization of historically contaminated soils may be a mechanism for transporting trace metals into green infrastructure systems. They found no clear relationships between infrastructure age and metal contamination. Finally, Al-Taani et al. also examined spatial patterns of metals, but in roadside dust along a 123-km stretch of the Abu Dhabi-Liwa Highway. They found roadside dust to be enriched above background levels for all metals except nickel and chromium. Contamination was most evident for cadmium and lead. Prevailing winds impacted the spatial distribution of road dust metal content.

Overall, this Research Topic highlights several important avenues and aspects of urban biogeochemical research. The value of long-term and spatially extensive data sets is clearly high and such data sets are needed into the future to assess long-term changes in water and overall environmental quality. The biogeochemical cycling in urban systems is highly complicated and this is compounded by unique features such as buried streams, aging infrastructure, and engineered stormwater management features. Ongoing combinations of field investigations, process driven experimentation and data syntheses, such as those collected in this Research Topic, are needed to be able to continue to unravel the biogeochemical processes that are unique and important to urban landscapes.

Author contributions

CM: Conceptualization, Writing–original draft. CO: Conceptualization, Writing–review and editing. SL: Conceptualization, Writing–review and editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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