Environmental Justice in the City: Socio-Economic Dimensions of Urban Stream Health

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Rationale and Objectives

Water quality is a critical aspect of urban environmental health, influencing ecosystem vitality and human well-being. Metropolitan areas, with their diverse and intense land use patterns and socio-economic disparities, present unique opportunities for understanding the dynamics of water quality. In urban settings, areas with lower socio-economic status often face greater environmental burdens, including poorer water quality (Davis et al., 2022; Horvath et al., 2022). This can result from various factors such as inadequate infrastructure, higher population densities, and limited resources for environmental management. Additionally, residents of these areas might lack the political power to advocate for environmental improvements, perpetuating a cycle of degradation. Conversely, higher socio-economic status areas may have better environmental conditions due to more substantial investment in infrastructure and environmental protection. Moreover, understanding how water quality varies with socio-economic disparities is important for identifying and addressing:

- **Environmental injustices** to ensure that all communities, regardless of their socio-economic status, have access to clean water and healthy ecosystems,
- **Public health issues** associated with exposure to harmful contaminants in surface waters, and
- **Effective policies and management** that consider the interplay between socio-environmental dynamics to better tailor management strategies.

While it is known that socio-economic status influences water quality, detailed spatial and temporal analysis of water quality across different socio-economic areas within urban settings is underexplored, especially within Tennessee. There is a need for more interdisciplinary research that integrates environmental science, urban planning, social science, and public health to provide a comprehensive understanding of the dynamics of water quality in metropolitan areas and inform more effective and inclusive water management practices. This proposal aims to investigate the water quality in streams within a metropolitan area, focusing on watersheds that span a socio-economic gradient. By doing so, we aim to elucidate the intricate interplay between environmental health, social equity, and sustainable urban development. Knoxville, with its contrasting socio-economic profiles between eastern and western regions (Fig. 1), offers an ideal setting for exploring these dynamics. The primary objectives of this study are:

1. Conduct a pilot study to assess water quality across socio-economic gradients
2. Generate hypotheses on causal mechanisms of uneven distribution of water quality and report in peer-reviewed article

![Figure 1. Gradient of socio-economic status in the Knoxville metropolitan area. Blue lines indicate streams and rivers.](image)
3. Secure funding for a broad-scope study of socioeconomic disparities in urban stream water quality and its impacts on ecosystem and human health

**Technical Approach and Research Plan**

The Knoxville metropolitan area will be used as a model-system in a pilot study to assess if the water quality of urban streams co-varies with the socioeconomic status of watershed residents. The arrangement of tributary stream watersheds in the Knoxville area make it an ideal system for mapping variation in socioeconomic status to hydrologic units. This contiguous urban area contains over 10 tributary streams of similar size that directly discharge to the Tennessee River. These tributaries primarily run north-to-south, so the strong gradient of socioeconomic status that spans from east-to-west cuts across watershed boundaries (Fig. 1).

The first step in this pilot study will be to develop and implement a method to quantify the socioeconomic status of people within urban stream watersheds. Available socioeconomic data is distributed by census tract, rather than watershed, so spatial analysis will be necessary to represent the socioeconomic status of each watershed. Census tracts will be spatially overlayed with watershed boundaries to quantify measures of central tendency and variability of socioeconomic status by watershed area. Additional factors, such as household characteristics, racial minority status, and housing type, will be obtained from U.S. Census survey data and summarized for each of Knoxville’s Tennessee River tributary streams. This information will be used to characterize overall socioeconomic status.

Next, the above-described analysis will be used in a study-design that measures water quality across a socioeconomic gradient. A minimum of three tributary streams, with watershed areas of low, medium, and high socioeconomic status will be chosen for inclusion in this pilot-study. A single station that is directly adjacent to the confluence with the Tennessee river and therefore representative of the water quality of the entire watershed will be established on each stream. Biological and chemical contaminants, and a suite of physicochemical water quality parameters that are known to be influenced by pollution will be measured repeatedly at each station. Direct measures of water quality are known to be strongly dependent on discharge so a temporal sampling design that captures the typical variation in each stream’s hydrology will be employed. Some biological contaminants that may be measured include, *Escherichia coli*, pathogens, biological oxygen demand (BOD), and/or biomarkers of wastewater contamination; chemical contaminants may include Per- and polyfluoroalkyl substances (PFAS), pesticides, insecticides, and/or heavy metals (e.g., mercury); the suite of physicochemical parameters will include temperature, dissolved oxygen, and pH.

Analyses of pilot data will be used to evaluate the causal relationships between socioeconomic status and water quality in a peer-reviewed scientific article. We predict that data will reveal a pattern of environmental injustice in Knoxville streams but that this relationship may depend on the water quality variable that was measured. Spatial analyses will be conducted to generate hypotheses on the sources of pollution contributing to water quality degradation and how they vary with socioeconomic status. Streams with watershed areas of low socioeconomic status may experience higher levels of pollution, which may be spatially-related to factors such as population density, intensity of development, waste and stormwater infrastructure, waste management practices, and quantity of green spaces and riparian areas. We expect streams with watershed areas with higher socioeconomic status to generally have lower levels of pollution of most contaminants due to better infrastructure, more rigorous environmental regulations, and greater community engagement in environmental protection efforts. However, certain chemical
contaminants, such as herbicides and pesticides that are related to costly lawn-care may be found in higher concentration in urban streams of higher socioeconomic status.

The pilot study, spatial analysis, and reporting in peer-review literature will lay a foundation for a highly competitive proposal for research funding. A proposal will be written to evaluate the ecological and human health impacts of the variables that are identified to contribute to environmental injustices at a broad scale. Co-PIs Engman and Hathaway are currently involved in research on urban streams in Puerto Rico and Michigan, respectively, so a study that incorporates these areas may be proposed. Alternatively, the proposed study may focus on Tennessee or the urban streams in the southeastern United States. In addition to the expanded spatial scope, this proposal will set forth a plan to explore the consequences of disparities in urban stream water pollution by measuring contaminant dynamics in stream food-webs, contaminant effects on ecosystem processes (e.g., leaf litter decomposition), and contaminant risk to local residents of from consumption of fish and use of streams for recreation.

**Collaboration Plan, including possible collaboration with ISSE researchers**

PIs Fidan and Engman are early-career researchers who have experience with assessing water quality and aquatic ecological health across diverse watersheds. Through collaborations with ISSE Associate Director Hathaway (co-PI with expertise in urban hydrology) we aim to lay the groundwork for a larger-scale proposal that quantifies the disproportionate impacts of water quality degradation in underserved communities and outlines restoration recommendations using community engagement avenues. To catalyze this collaboration, we will have a kick-off meeting with all project members upon award dissemination and regular monthly meetings to share project updates. Project progress will be managed by Lead PI Fidan.

**Proposal Development Plan**

The PIs plan to extend this proposal to a larger spatial extent to provide a comprehensive understanding of the spatial distribution of environmental hazards and the corresponding health outcomes, focusing on vulnerable populations. Ultimately, this research will contribute to the creation of more resilient and just communities, ensuring that environmental benefits are accessible to all, irrespective of socio-economic status or geographical location. We will target two agencies, NSF Dynamics of Integrated Socio-Environmental Systems ($250,000) and EPA Environmental and Climate Justice ($2,000,000), strongly interested in funding this work.

**Dissemination Plan**

This project will result in one peer reviewed publication to disseminate results to the academic community, possible venues include *Science of the Total Environment* and *Environmental Science & Technology*. Industry and public sectors will be reached by presenting our results at both a national level conference (e.g., the Symposium for Urban Stream Ecology and Society for Freshwater Science) and a state level conference (e.g., Tennessee Water Resources Symposium), ensuring a broad audience is exposed to our work.

**Timeline**

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