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The Impact of Surrounding Concrete Temperature on Dissolved Oxygen Levels in Flowing Streams: A Pilot Study

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Abstract

As water warms, oxygen solubility decreases, which directly affects aquatic life. This relationship is critical for maintaining aquatic life, especially in urban environments where water bodies are often impacted by human activities. Concrete, a material widely used in urban infrastructure, has a high thermal mass, which leads to elevated air and surface temperatures, which are transferred to adjacent water bodies, raising their temperatures as well. Given that higher temperatures result in lower oxygen solubility, the elevated temperatures in urban streams may lead to hypoxic conditions, disrupting the balance of aquatic ecosystems. This phenomenon is particularly concerning because urban streams often serve as critical habitats for wildlife, despite their proximity to human activities. Although considerable research has focused on urbanization's effects on stream temperature and water quality, the specific role of surrounding concrete on dissolved oxygen levels remains underexplored. This pilot study was conducted over a period of thirteen months to explore the relationship between surrounding concrete mass of flowing urban streams and the dissolved oxygen.

Keywords

Dissolved Oxygen, Urban Streams, Concrete Temperature, Water Temperature, Urban Heat Islands, Riparian Vegetation

1. Introduction

Water quality is one of the most crucial elements for sustaining aquatic ecosystems. It dictates the health and survival of organisms, from microscopic plankton to large fish. Among various water quality parameters, dissolved oxygen (DO) is paramount because it directly affects the respiration of aquatic organisms [1]. The capacity of water to hold dissolved oxygen is inversely related to its temperature: as water warms, its ability to retain oxygen decreases [2]. This relationship is critical for maintaining aquatic life, especially in urban environments where water bodies are often impacted by human activities.

Urbanization, with its proliferation of impervious surfaces like concrete, has created a unique challenge for maintaining water quality in streams and rivers. Concrete, a material widely used in urban infrastructure, has a high thermal mass, meaning it absorbs and retains heat from the sun. In urban areas, this leads to elevated air and surface temperatures, which are transferred to adjacent water bodies, raising their temperatures as well [3]. Given that higher temperatures result in lower oxygen solubility, the elevated temperatures in urban streams may lead to hypoxic conditions, disrupting the balance of aquatic ecosystems. This phenomenon is particularly concerning because urban streams often serve as critical habitats for wildlife, despite their proximity to human activities.

The interplay between urbanization and water quality is complex, but one consistent observation is that streams surrounded by concrete and impervious surfaces tend to experience higher water temperatures. This heat, absorbed by the surrounding concrete, directly impacts the stream’s thermal regime. The higher the temperature, the less oxygen the water can hold, which can result in decreased dissolved oxygen (DO) levels. This has profound implications for stream ecology, potentially leading to hypoxic conditions, where DO levels fall below those required for aquatic organisms to thrive.

Although considerable research has focused on urbanization's effects on stream temperature and water quality, the specific role of surrounding concrete on dissolved oxygen levels remains underexplored. While concrete surfaces are well-documented for their ability to absorb and retain heat, their impact on the nearby flowing water has not been sufficiently studied. This study seeks to bridge this gap by investigating whether urban streams surrounded by higher percentages of concrete exhibit elevated temperatures and reduced dissolved oxygen levels compared to streams located in less urbanized areas. The study focuses on two creeks in the metro Atlanta area—Sope Creek and Sewell Mill Creek—chosen because they represent sites with varying levels of surrounding concrete cover, allowing for a comparative analysis of how concrete affects these critical water quality parameters.

2. Hypothesis

We hypothesize that urban streams with a higher percentage of surrounding concrete will have higher water temperatures due to the heat-absorbing properties of concrete. This increase in water temperature may, in turn, reduce the water’s ability to retain dissolved oxygen, leading to lower dissolved oxygen concentrations in these streams. Conversely, streams in areas with less concrete cover may experience cooler water temperatures and higher dissolved oxygen levels because of the reduced heat retention by the surrounding surfaces. This hypothesis is grounded in the principle that the thermal properties of concrete will exacerbate the urban heat island effect, creating a localized temperature increase in urban streams that directly impact oxygen solubility.

3. Literature Review

The urban heat island (UHI) effect, wherein urban areas experience higher temperatures than their rural counterparts, is a well-established phenomenon, primarily driven by impervious surfaces such as concrete, asphalt, and buildings [4]. These materials absorb solar radiation during the day and release heat at night, leading to elevated air temperatures, which can affect nearby water bodies. In urban streams, this increase in temperature can disrupt the natural thermal dynamics that support aquatic organisms. The UHI effect has been widely studied, with many researchers observing that urbanization leads to higher temperatures in nearby streams, which may reduce the dissolved oxygen content necessary for aquatic survival.

Several studies have established that urban streams often have higher temperatures than their rural counterparts [5], a trend linked to the density of impervious surfaces in the watershed [6]. The increased runoff, decreased infiltration, and reduced natural cooling mechanisms in urbanized watersheds exacerbate the warming of urban streams. This temperature increase can reduce the solubility of oxygen, leading to lower dissolved oxygen levels, which are critical for the survival of aquatic organisms [7]. Urbanization also leads to changes in stream hydrology, with altered flow patterns and reduced base flow contributing to warmer temperatures and lower oxygen availability.

Moreover, elevated water temperatures can also increase microbial activity and respiration, further depleting dissolved oxygen levels [8]. This combination of factors can lead to hypoxic or even anoxic conditions, which disrupt the ecological balance of aquatic ecosystems. Additionally, higher temperatures can increase the metabolic rate of aquatic organisms, further increase oxygen demand and contribute to hypoxic conditions [9]. As a result, streams with elevated temperatures may experience a cascade of negative effects, including reduced biodiversity and altered species composition.

Despite the well-established link between urbanization and changes in stream temperature, most research has focused on broad urbanization patterns and their impact on water quality, without specifically isolating the effects of concrete surfaces. The thermal properties of concrete and their specific influence on stream temperature and dissolved oxygen remain underexplored, especially in flowing water bodies where the effects may vary with stream dynamics. While concrete surfaces have been recognized for their heat-absorbing properties, their impact on stream ecosystems is yet to be fully understood. Understanding this relationship is crucial for developing targeted mitigation strategies that address the challenges posed by urbanization to aquatic environments.

4. Methodology

This study was conducted in the Metro Atlanta area, with the goal of assessing the effects of surrounding concrete on water quality in two urban streams: Sope Creek and Sewell Mill Creek. These creeks were chosen due to their proximity to areas with varying levels of concrete cover, allowing for a comparative analysis of how concrete affects stream temperature and dissolved oxygen levels. Both creeks are representative of urban streams that face typical pressures from surrounding urban infrastructure, making them ideal study sites.

The methodology was structured as follows:

1) Site Selection: Two locations within each creek were selected—one site with high concrete abundance and one site with low concrete abundance. The high-concrete sites were located near areas with significant urban infrastructure, such as roads and parking lots, while the low-concrete sites were located near parks or less developed areas. The percentage of impervious surfaces within a 500-foot radius of each site was used to categorize sites as "high" or "low" concrete. This categorization allowed for a direct comparison of the impact of surrounding concrete on water temperature and dissolved oxygen.

2) Data Collection: Monthly data was collected from March 2024 to March 2025 at each site. The following parameters were measured:

- Air Temperature (˚C): To assess ambient environmental conditions.
- Water Temperature (˚C): To determine the temperature of the stream water.
- Dissolved Oxygen (DO) (mg/L): To measure the oxygen content in the water.
- pH: To monitor the acidity or alkalinity of the water.
- Concrete Temperature (˚C): To measure the temperature of surrounding concrete surfaces.
- Humidity (%): To provide context for how moisture in the air affects temperature dynamics.
- Heat Index (˚C): A combined measure of temperature and humidity.

3) Equipment: A standard Adopt-a-Stream water quality monitoring kit [10] was used for measuring air temperature, water temperature, and dissolved oxygen. For measuring concrete surface temperature, a Kestrel Drop thermometer [11] was used. This tool provided precise temperature measurements of surrounding surfaces, which was crucial for understanding the heat retention properties of concrete.

4) Site Conditions: Each site was selected for the presence of riparian vegetation, which helps to moderate the direct impact of sunlight on the water surface. Measurements were taken within one foot of the surface to minimize the effects of stream depth on temperature readings. Sampling was suspended during rainfall events to prevent alterations to the water quality and temperature, which could skew the results.

5) Impervious Surface Assessment: A critical component of the methodology was the assessment of surrounding impervious surfaces. Four key sites were evaluated based on their concrete coverage:

- East Cobb Park: <5% concrete coverage (low concrete)
- Pope High School: 60% - 70% concrete coverage (high concrete)
- Marietta Power and Water: 60% concrete coverage (high concrete)
- Townsend Trail: 10% - 15% concrete coverage (low concrete)

To access the results in the Adopt-a-stream database for these creeks:

1) Go to https://aas.gaepd.org/

2) Hover the cursor over "Citizen Monitoring" tab at the top of the page and click "Sites" from the dropdown menu.

3) In the search bar, type the site number (S-####), detailed in table below.

4) Open the link for "Recorded Monitoring Events".

5. Results

Data were analyzed for each site, and median values for key parameters were calculated. The following Table 1 summarizes the results:

Table 1. Results in median values.

Site Location	Air Temp (˚C)	Water Temp (˚C)	DO (mg/L)	pH	Concrete Temp (˚C)	Humidity (%)	Heat Index (˚C)
Sope Creek High Concrete (S-7845)	22.0	17.0	9.3	7.12	28.88	27.95	25.25
Sope Creek Low Concrete (S-7846)	22.0	17.75	8.65	6.99	26.5	30.45	26.08
Sewell Mill Creek High Concrete (S-7847)	21.0	16.0	7.8	6.62	25.72	33.1	26.61
Sewell Mill Creek Low Concrete (S-7549)	20.75	16.5	8.45	6.87	23.91	39.25	23.13

To determine if there were statistically significant differences in dissolved oxygen levels between the high-concrete and low-concrete sites, a two-sample t-test was performed. The results indicated no significant differences in dissolved oxygen concentrations ($p > 0.05$). This suggests that the surrounding concrete did not have a significant effect on the DO levels at the sites studied.

Furthermore, the maximum difference in water temperature between high and low concrete sites was 0.75˚C, a relatively small variation. This small temperature difference likely did not have a significant impact on dissolved oxygen levels, supporting the lack of significant findings. The absence of a strong relationship between surrounding concrete and dissolved oxygen suggests that other factors, such as riparian vegetation and groundwater dynamics, may play a more significant role in moderating water temperature and DO concentrations.

6. Discussion

Contrary to our hypothesis, which was in line with larger studies [12], the results showed no significant differences in dissolved oxygen (DO) levels between the high-concrete and low-concrete sites. While we initially expected urbanized areas with greater concrete cover to exhibit reduced DO due to elevated water temperatures, several factors may help explain this outcome.

One likely explanation is the presence of increased riparian vegetation in the Metro Atlanta area, which appears to play a critical role in mediating temperature fluctuations in aquatic ecosystems. Riparian vegetation provides shade that reduces direct solar radiation, thereby limiting thermal inputs to the stream. In addition, vegetated riparian zones can enhance groundwater infiltration, which often delivers cooler subsurface water to streams, and promotes evapotranspiration processes that further regulate local microclimates. These combined mechanisms likely contributed to stabilizing water temperatures across both site types, effectively buffering the thermal effects that would otherwise result from concrete's high heat absorption and retention properties. Thus, even in high-concrete environments, well-established riparian zones may offset some of the negative thermal impacts associated with urbanization.

Another important factor to consider is the magnitude of temperature differences observed between sites. In this study, the maximum difference between high- and low-concrete locations was only 0.75˚C. While it is well established that oxygen solubility decreases as water temperature increases, this small variation may have been insufficient to produce detectable changes in DO concentrations. Previous research suggests that more substantial thermal shifts—typically several degrees Celsius—are often required before clear and measurable declines in DO are observed. This points to a potential threshold effect, where minor increases in temperature have little to no observable impact, but larger and more sustained increases can significantly alter DO dynamics.

It is also worth acknowledging that DO is influenced by a complex interplay of physical, chemical, and biological processes, not just temperature alone. For instance, factors such as flow rate, turbulence, primary production, and organic matter decomposition can strongly influence oxygen concentrations. If these processes were relatively consistent across both high- and low-concrete sites, they may have masked any subtle temperature-driven differences. Similarly, temporal variations such as diel cycles in temperature and oxygen or seasonal fluctuations—could have influenced the data, potentially obscuring trends associated with concrete cover.

Taken together, these findings highlight the resilience of stream ecosystems in certain urbanized contexts, particularly when riparian buffers are intact. However, they also underscore the importance of considering multiple environmental drivers when assessing water quality. Future research could benefit from examining sites with greater variability in riparian vegetation, larger gradients of impervious surface cover, or stronger seasonal contrasts to determine whether more pronounced patterns in DO emerge under different conditions.

7. Limitations

Sample Size and Scope: The study focused on only two streams and four sites, which presents a narrow dataset. Given the limited geographic scope and number of study sites, it is possible that the findings don't account for the diversity of urban conditions and variations in environmental factors such as stream size, watershed characteristics, or urban development patterns. As a result, the observed effects of concrete may differ in other areas, so the results cannot be generalized to a broader range of urban streams or ecosystems. Additionally, the small sample size may have reduced the statistical robustness of the findings, making it difficult to confidently extrapolate to other urban streams.

Short-Term Data: Data collection occurred monthly over a thirteen-month period, which, while providing valuable insights, is insufficient to capture the dynamic and highly variable nature of aquatic ecosystems. Factors such as dissolved oxygen and water temperature can fluctuate dramatically on shorter timescales due to weather conditions (e.g., temperature, rainfall), stream flow dynamics, or even shading from surrounding vegetation. Monthly sampling intervals may have missed important daily or seasonal fluctuations that could affect the study's conclusions. For example, heat spikes during summer or cold fronts could significantly alter water temperatures in ways that monthly data might not reveal. Without high-frequency data, the study might overlook key drivers of environmental change.

Effect of Riparian Vegetation Not Isolated: Although our study suggests that riparian vegetation (plants along the stream's edge) mitigates the impact of surrounding concrete, it didn't systematically account for or quantify vegetation cover at each site. This oversight makes it difficult to isolate the specific effects of concrete on stream temperature or oxygen levels. Riparian vegetation provides shade, filters runoff, and stabilizes soil, which could reduce the heating effects of concrete, so the lack of a systematic measure means it's hard to distinguish between the influence of vegetation and concrete. Without controlling for vegetation cover, the study cannot conclusively determine whether concrete alone has a significant impact, or if the presence of vegetation is the primary factor responsible for the observed results.

Weak Statistical Power: The study reported a small temperature difference (0.75˚C) between sites, which, in statistical terms, is a very modest effect. With such a small effect size, it becomes challenging to draw meaningful conclusions. A t-test was used to compare the temperature differences, but the lack of significant findings could be due to the relatively small variation in temperature between the study sites. This raises the concern that the study may not have sufficient statistical power to detect a real difference if one existed. To strengthen the results, a larger sample size, more frequent data collection, or more sensitive statistical tests such as multivariate models could be employed.

Intrinsic Limitation of the Study Design: In flowing water systems like streams, the direct heating effect of surrounding concrete may be naturally diminished due to the high mixing and cooling capacity of moving water. Streams tend to have a high rate of water exchange, meaning any localized heating from concrete surfaces may quickly dissipate through mixing and water flow dynamics. As a result, the study may be inherently limited in its scope because it focuses on a potential effect that may have minimal relevance in natural systems. Other urban features—such as stormwater runoff, altered channel morphology, or the removal of shading—might have a much more significant impact on stream temperatures and water quality. Thus, the study's focus on concrete may overlook more critical drivers of stream health in urban environments.

8. Conclusions

This pilot study provides valuable insights into the relationship between surrounding concrete and water quality in urban streams. While concrete surfaces absorb heat and could potentially raise stream temperatures, the presence of riparian vegetation appears to mitigate these effects, maintaining dissolved oxygen levels. These findings suggest that factors other than concrete, such as vegetation and groundwater dynamics, may play a more significant role in determining water quality. Further research, particularly over longer periods and with more diverse study sites, is necessary to understand the long-term impacts of urbanization on stream ecosystems.

Future Research Directions

Future studies should address several gaps identified in this study:

- Larger and more diverse sample sizes: Expanding the study to more sites across different regions and urban environments will help to generalize the findings.
- Longer study periods: To capture seasonal and extreme weather effects, longer-term monitoring is essential.
- Riparian vegetation studies: Future studies should more directly examine the role of riparian vegetation in buffering the effects of surrounding urban infrastructure on water quality.
- Comprehensive urban features analysis: Additional research should investigate other urban features, such as stormwater infrastructure and roadways, and their combined effects on water quality.

Understanding the impact of urban infrastructure on stream ecosystems is crucial for urban planning and stream management, especially as urbanization continues to expand. By focusing on factors like concrete, vegetation, and groundwater flow, future research can help inform strategies for preserving water quality in urban streams and mitigating the negative impacts of urbanization on aquatic ecosystems.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] U.S. Geological Survey (2018) Dissolved Oxygen and Water. https://www.usgs.gov/special-topics/water-science-school/science/dissolved-oxygen-and-water

[2] U.S. Environmental Protection Agency (2024) Dissolved Oxygen.

https://www.epa.gov/caddis/dissolved-oxygen

[3] U.S. Geological Survey (2018) Specific Heat Capacity and Water. https://www.usgs.gov/water-science-school/science/specific-heat-capacity-and-water

[4] Phelan, P.E., Kaloush, K., Miner, M., Golden, J., Phelan, B., Silva, H., *et al.* (2015) Urban Heat Island: Mechanisms, Implications, and Possible Remedies. *Annual Review of Environment and Resources*, **40**, 285-307. https://doi.org/10.1146/annurev-environ-102014-021155

[5] Nelson, K.C. and Palmer, M.A. (2007) Stream Temperature Surges under Urbanization and Climate Change: Data, Models, and Responses. *Journal of the American Water Resources Association*, **43**, 440-452. https://doi.org/10.1111/j.1752-1688.2007.00034.x

[6] EPA (2012) Urbanization and Streams: Studies of Hydrologic Impacts. https://archive.epa.gov/water/archive/web/html/report.html

[7] Ali, B.A. and Mishra, A. (2022) Effects of Dissolved Oxygen Concentration on Freshwater Fish: A Review. *International Journal of Fisheries and Aquatic Studies*, **10**, 113-127. https://doi.org/10.22271/fish.2022.v10.i4b.2693

[8] Stanford, J.A., Ward, J.V., Zimmermann, H.J. and Cline, L.D. (1986) The Colorado River System. In: *Monographiae Biologicae*, Springer, 353-423. https://doi.org/10.1007/978-94-017-3290-1_9

[9] Rubalcaba, J.G. (2024) Metabolic Responses to Cold and Warm Extremes in the Ocean. *PLOS Biology*, **22**, e3002479. https://doi.org/10.1371/journal.pbio.3002479

[10] Georgia Adopt-A-Stream. https://adoptastream.georga.gov/

[11] Kestrel Instruments. https://kestrelinstruments.com/data-loggers

[12] Timm, A., Ouellet, V. and Daniels, M. (2021) Riparian Land Cover, Water Temperature Variability, and Thermal Stress for Aquatic Species in Urban Streams. *Water*, **13**, Article 2732. https://doi.org/10.3390/w13192732