EVALUATING WATER RESILIENCE AND SUSTAINABILITY IN URBAN GOLF COURSES THROUGH WATER QUALITY MONITORING

Xiaozi Pan
The Experimental High School Attached to Beijing Normal University, Beijing, China
18518711106@163.com

ABSTRACT:

Urban water systems are often vulnerable to changes in the local environment resulting from pollution, ecological imbalance, excessive surface runoff induced by heavy rainfall, and climate change. While rapid urbanization is often accompanied by these challenges, urban golf courses have been proposed as an effective way to counteract many of these issues. To evaluate water resilience and sustainable management of urban golf courses in reference to the Sustainable Development Goals (SDGs) outlined by the UN, this study investigates the water quality, nutrient levels, and heavy metal concentrations of two urban golf courses in Beijing, China. Water samples were taken from various spatial sections of surrounding water bodies, including surface-level supernatant and bottom sediments. Results show no significant pollutants and heavy metal concentration for either site, suggesting their potential roles in fostering urban sustainability and water resilience in aspects like stormwater retention, pollutant buffering and neutralization, and ecosystem services provision. These results provide valuable insights into urban planning and management for urban golf course stakeholders and environmental policymakers aiming to enhance urban water resilience in line with global sustainability targets.

KEYWORDS:
Urban Water Resilience, Golf Course, Water Quality, Sustainability, Nutrient Leaching, Pollution, Heavy Metal Ions, Stormwater Retention, Ecosystem Services

INTRODUCTION

Urbanization and climate change have imposed large ecological footprints on hydrology and water quality, such as increased runoff and pollution, decreased groundwater recharge, and water quality degradation (Grimm et. al, 2008). However, cities and urban environments may serve as both problems and solutions, as city infrastructure or recreational spaces like golf courses may serve a variety of functions that could mitigate environmental issues that arose from urban landscapes in the first place (Grimm et. al, 2008). Since these environmental challenges are highly relevant to the Sustainable Development Goals (SDGs) proposed by the United Nations, specifically goal #6, clean water and sanitation, and goal #14, life below water (United Nations, n.d.), it is imperative to closely monitor water quality, document concentrations of pollutants, and seek the source of contamination to facilitate the maintenance of clean water and an acceptable environment for aquatic life. Since the first step to properly achieve these goals is to accurately identify and assess local water quality issues, this study aims to evaluate the resilient water management in the context of sustainability by taking water samples from two golf courses in Beijing.

Beyond the apparent recreational value of golf courses, they can also offer several key environmental benefits in an urban context. For instance, compared to concrete or asphalt surfaces, grass and low-height vegetation surfaces on golf courses are beneficial for effective stormwater infiltration (Cook & Foster, 2020). The green spaces of golf courses offer non-piped solutions to stormwater storage, which may direct a portion of water flow away from and relieve the stress of the underground drainage pipe system under heavy downpour conditions (Cettner et al., 2013). In addition, well-managed golf courses may cool off the surrounding environment, counteract the urban heat island effect, and provide more ecological niches for diverse organisms to occupy, thus contributing to urban biodiversity (Nguyen et al., 2022).

Despite these merits, multiple issues have traditionally been associated with urban golf courses worldwide, such as the heavy use of water and nutrient leaching (Shuman, 2002). Heavy metal pollution may also result from recycling e-waste near urban environments (Luo et al., 2011), which is liable to leach into surrounding water bodies. These issues may be further exacerbated by unoptimized irrigation practices (Afzal et al., 2024), which may lead to eutrophication and toxicity accumulation in the local ecosystem (Liu et al., 2018). Therefore, in order for golf courses to provide key ecosystem services in an urban landscape, it is imperative to ascertain that the golf courses are well-managed and that the quality of water bodies adjacent to the courses is regularly examined. The water quality of golf courses may thus act as an indicator for sustainability that may allow the provision of ecosystem services like the construction of ecological niches, efficient irrigation practices, and effective stormwater infiltration or retention.

This study investigates the water quality and pollutant concentrations in the water bodies surrounding the Beijing Wanliu Golf Course and the Beijing Qinghewan Golf Course, two major urban golf resorts. Water quality data from these golf courses may advise key stakeholders on regulating golf courses in areas such as monitoring and irrigation practices, and provide data-driven insight for policy-makers to adjust environmental guidelines pertaining to golf course management to align with the UN SDGs and foster urban water resilience.

METHODS

Sampling Date, Time, and Location

The location of sampling was the Beijing Wanliu Golf Course (site 1) in the Haidian District of Beijing, an urban environment surrounded by a park and highways, and the Beijing Qinghewan Golf Course (site 2) at the intersection of Haidian and Chaoyang

District of Beijing, an urban environment next to the Qinghe river.

At site 1, sampling was conducted on April 4th, 2025 between 12:00 noon and 5:30 pm. The temperature was 20 degrees Celsius and the humidity was at 8% (China Meteorological Administration, n.d.). No precipitation was recorded.

At site 2, sampling was conducted on May 21st, 2025 between 9:00 am and 12:00 noon. The temperature of 23 degree Celsius and the humidity was at 37% (China Meteorological Administration, n.d.). No precipitation was recorded.

Sampling and Analysis Materials

At Site 1, water quality was assessed using key indicators, including pH, Dissolved Oxygen, and the concentrations of Ammonia (NH4+), Nitrite (NO2-), and Phosphorus. The overall presence or absence of heavy metal ions, including Lead (Pb), Cadmium (Cd), Mercury (Hg), and Copper (Cu), was tested with freshwater heavy metal testing kits.

At Site 2, water quality was assessed with different heavy metal testing kits that specifically focus on cadmium, magnesium, iron, copper, mercury, lead, and zinc ions. These kits were used to reduce the batch effect and produce more accurate results. In addition, the pH and the concentration in micrograms per liter of NO2, NO3, NH3, and PO4 were tested using respective testing kits.

Sampling and Analysis Procedures

Samples from water sources around the golf course were taken at regular intervals during the sampling period. To ensure a more well-rounded reflection of nutrient or pollutant concentrations, samples were taken from both the supernatant at the surface of water bodies and the bottom with sediments.

Samples were taken from 5 locations before turfgrass irrigation and 2 locations taken afterwards from Site 1, and a overall of 6 locations taken from Site 2. One sample was taken per location in Site 1, and three samples were taken from each location in Site 2 during the sampling period.

The samples were collected in 50 mL Falcon tubes and tested with test kits on the same day they were taken to prevent changes in their composition from microbial activity and decomposition. The numeric average of the tested results of the samples from each location in Site 2 constituted the final reported results for Site 2. The resulting data was plotted into charts with MS Excel.

RESULTS

At site 1, as shown in Table 1 below, Samples 1, 2, 3, 5, and 6 were taken before turfgrass irrigation, and samples 4 and 7 were taken after irrigation. Samples 3 and 4 were taken from close vicinities of each other to reflect the changes resulting from irrigation, and so were samples 6 and 7.

Table 1: The pH, dissolved oxygen, and concentration levels of pollutants in samples taken from Site 1 before and after irrigation

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
Irrigation Timing	Before	Before	Before	After	Before	Before	After
Location Description	dark brown water color; plastic bags are present; planktons are present	clearer waters; planktons are present	Murkier waters with green-yellow colored waters; water accumulated at lower soil surfaces nearby after irrigation		dark-green colored waters; yellowish-colored weeds are present	light-green colored waters and clearer; no planktons are present; water accumulated at lower soil surfaces nearby after irrigation	
Phosphates (mg/L)	0.3	0.2	0.2	0.5	0.1	0.1	0.6
Nitrite (mg/L)	0	0	0	0	0	0	0
Ammonia (mg/L)	0	0.1	0.1	0.1	0	0	0.1
pH	7.8	7.4	7.8	7.6	8	8	8
Dissolved Oxygen (mg/L)	2	7	6	6	7	6	6
Heavy Metal Ions	Trace Amounts	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present

It may be observed from Table 1 that the pH, ammonia, and nitrite levels across all samples stayed relatively constant. Sample 1 had significantly lower dissolved oxygen levels and trace amounts of heavy metal ions present, which is different from the rest of the samples. This may have been due to localized pollution, which may be seen from the darker water colors and the presence of plastic bags and other human-induced pollution in the vicinity. Apart from Sample 1, no other samples showed the presence of heavy metal ions.

Comparing samples 3 and 4 and samples 6 and 7, one may clearly discern that all other data, including nitrite, ammonia, pH, dissolved oxygen, and the absence of heavy metal ions, remained the same before and after irrigation. The only difference was the concentrations of phosphates in the samples, which rose by a factor of 2.5-6 folds after irrigation. The golf course employs a strategy of sprinkler irrigation, which has a reputation for conserving water and reducing the nutrient leaching from adjacent soil (Kohler et al., 2004). However, it was observed that the geographical distribution of sprinklers was uneven in a few locations of the golf course, resulting in some overlapping regions of the circular patterns of adjacent sprinklers; windy conditions may also have affected the water distribution, which could have made some regions receive more water than others (Foreign Agricultural Service, 2024). These conditions may have resulted in the observed accumulation of extra water that has yet to percolate the soil after irrigation ended. Samples 4 and 7 were both taken in locations with such kind of accumulated water, which may have contributed to the accumulation of phosphates in these locations.

However, even though a relatively higher level of nutrient levels marked by phosphate concentration was found after irrigation in Site 1, it remained well below the recommended limit for irrigation water (Foreign Agricultural Service, 2024). Localized low levels of dissolved oxygen and trace amounts of heavy metal ions in sample 1, while present, made up the vast minority of all samples taken, reflecting little significant change in pollutant concentrations before and after irrigation.

Table 2: The pH and concentrations of pollutants in samples taken from Site 2

Samples	1	2	3	4	5	6
NO2 (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
NO3 (mg/L)	10	10	10	10	25	25
NH3 (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Heavy Metals (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
PO4 (mg/L)	0.1	0.1	0.1	1	0.1	1
PH	8	8	8	7.8	7.8	7.8

At Site 2, it can be observed from Table 2 that the water quality was consistently excellent, with the pH relatively stable throughout all 6 samples. The concentrations of NO2, NH3, and heavy metals, including Pb, Cd, Zn, Mn, Hg, Fe, and Cu, were negligible or not detected. Even though the concentrations of NO3 and PO4 varied from sample to sample, they did not constitute a significant level of concentration that may negatively impact water quality at Site 2.

It is also worth noting that all water samples taken at Site 2 were clear and free of visible pollutants and microorganism growth. The water quality at Site 2 was thus assessed to be good and well within the standards of local recreational water regulations (Foreign Agricultural Service, 2024).

DISCUSSION

Both sites 1 and 2 showed relatively effective nutrient management in light of their low nitrate and phosphate concentrations. Such good water quality suggests strong water resilience at both sites, as the local water systems can robustly resist or recover from environmental stressors such as pollution and climate change. Low or no concentrations of heavy metal ions present at both sites suggest that pollution is being actively managed as a part of ongoing processes at these sites, indicating the presence of buffers or relatively fast recovery rates that dull the impact of incoming pollution (Luo et al., 2011).

Good water quality at these sites also suggests that they are able to support healthy aquatic ecosystems, which may form a positive feedback loop by helping to mediate environmental stressors and improve water quality as a nature-based solution. Healthy local ecosystems contribute to increasing the resilience of the water body by fostering the maintenance of its self-sustaining functions in ecology over time (Nguyen et al., 2022). Robust systems such as sites 1 & 2 include a thriving local ecosystem encompassing a variety of open ecological niches for diverse organisms to occupy.

From a socioeconomic perspective, good water quality at these sites indicates the absence of nutrient leaching or pollution in adjacent water bodies surrounding the golf courses, which results in a robust water network that allows reliable access by the local community, dependably contributing to economic growth and fulfilling local recreation needs. The socioeconomic implications of healthy local water systems cannot be overlooked when assessing the resilience of urban water systems.

CONCLUSIONS

In conclusion, this study examined the water quality of water bodies surrounding two golf courses in urban Beijing to show that golf courses with good water quality may foster urban water resilience and demonstrate sustainable practices. As multifunctional green infrastructure, well-managed golf courses can be placed at key strategic locations in urban environments as nature-based solutions to maintaining a sustainable landscape.

Future research may include a longitudinal element to investigate how the water quality of golf courses changes over time and how this change relates to their capacity to contribute to resilient urban water management. More golf courses may also be evaluated in subsequent studies to construct an urban golf course landscape that may have interconnected effects with broader ecological implications.

REFERENCES

1. Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. *Science, 319*(5864), 756–760.
2. United Nations. (n.d.). *Sustainable development goals*. United Nations. https://www.un.org/sustainabledevelopment/ Retrieved May 21st, 2025
3. Cook, Foster, "Resilient Golf Course Design: Renovating Eaglewood Golf Course to Improve Stormwater Management & Increase Wildlife Habitat" (2020). *All Graduate Plan B and other Reports, Spring 1920 to Spring 2023*. 1480.
4. Cettner, A., Ashley, R., Hedström, A., & Viklander, M. (2013). Stormwater management and urban planning: Lessons from 40 years of innovation. *Journal of Environmental Planning and Management, 56*(6), 786–801. https://doi.org/10.1080/09640568.2012.706216
5. Nguyen, T.T.; Eslick, H.; Barber, P.; Harper, R.; Dell, B. Cooling Effects of Urban Vegetation: The Role of Golf Courses. Remote Sens. 2022, 14, 4351.
6. Shuman, L. M. (2002). Phosphorus and nitrate nitrogen in runoff following fertilizer application to turfgrass. *Journal of Environmental Quality, 31*(5), 1710–1715. https://doi.org/10.2134/jeq2002.1710

7. Luo C, Liu C, Wang Y, Liu X, Li F, Zhang G, Li X. 2011. Heavy metal contamination in soils and vegetables near an e-waste processing site, South China. J Hazard Mater. 186(1):481-90.
8. Afzal, M., Muhammad, S., Tan, D., Kaleem, S., Khattak, A. A., Wang, X., Chen, X., Ma, L., Mo, J., Muhammad, N., Jan, M., & Tan, Z. (2024). The Effects of Heavy Metal Pollution on Soil Nitrogen Transformation and Rice Volatile Organic Compounds under Different Water Management Practices. Plants, 13(6), 871.
9. Liu, J., Cao, W., Jiang, H., Cui, J., Shi, C., Qiao, X., Zhao, J., & Si, W. (2018). Impact of heavy metal pollution on ammonia oxidizers in soils in the vicinity of a tailings dam, Baotou, China. *Bulletin of Environmental Contamination and Toxicology*, 101, 110–116.
10.China Meteorological Administration. (n.d.). Meteorological data. CMA. https://data.cma.cn/forecast/index.html Retrieved April 4th, 2025
11.Foreign Agricultural Service. (2024). *China: National Standard for Irrigation Water Quality*. United States Department of Agriculture. https://www.fas.usda.gov/data/china-national-standard-irrigation-water-quality Retrieved April 5th, 2025
12.Kohler, E. A., Poole, V. L., Reicher, Z. J., & Turco, R. F. (2004). Nutrient, metal, and pesticide removal during storm and nonstorm events by a constructed wetland on an urban golf course. Ecological Engineering, 23(4–5), 285–298.