Sustainable *in situ* Water Treatment through Nature-based Solutions: Addressing Eutrophication in Urbanized Reservoir

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The growing water scarcity at a global scale and wastewater from industrial sites, in addition to urban agglomerations, discharging into surface water are of great and increasing environmental, economic and societal concern. The urbanized reservoir in the municipalities of Ibirité, Betim, and Sarzedo in Minas Gerais, Brazil, is a eutrophic aquatic ecosystem. Previous data show that water quality, local biodiversity, and consequently, multiple water uses are compromised. In this context, Nature-based Solutions (NBS) have emerged as an integrated approach for sustainable and resilient urban development, aiming to improve environmental quality. This work gathers literature data regarding the application of NBS as sustainable and effective alternatives for treating surface water from eutrophic aquatic systems. Despite the broad use of wetlands as NBS, results show a lack of different full-scale applications.

Introduction

The escalating crisis of global water scarcity demands innovative approaches to managing and treating water resources. Urban development plays a significant role in this challenge. As cities expand, the demand for water increases significantly, placing a strain on existing supplies regarding quantitative and qualitative aspects. Additionally, industrial and municipal wastewater discharge potentially pollutes surface water streams, further compromising their quality and availability [1]. These factors contribute to the eutrophication of vital aquatic ecosystems, a condition characterized by excessive nutrient levels that disrupts the delicate balance of these systems. Eutrophication leads to a decline in water quality, diminished local biodiversity, and ultimately, restricts multiple beneficial uses of the water [2].

Conventional water treatment methods, while effective, often come with high operational costs and environmental footprints. Therefore, this scenario necessitates the exploration of more sustainable solutions that are not only efficient but also in harmony with natural processes. In this sense, Nature-Based Solutions (NBS) have emerged as a promising approach for treating surface water in eutrophic aquatic ecosystems. NBS represent a paradigm shift towards integrated solutions that mimic natural processes for environmental restoration and resilience [3]. Furthermore, Nesshöver et al. [4] define NBS as determined by natural ecosystem services that include natural attenuation processes, usually involving the microbial removal of pollutants from water systems and are considered alternatives to engineered infrastructures that require investments.

This study specifically focuses on the application of NBS for water treatment, highlighting solar photolysis, a natural process driven by sunlight.

Material and Methods

A combined study of bibliometric analysis and systemic analysis of the literature was used to determine the latest developments regarding the application of NBS to treat eutrophic surface water in the last 10 years (2014–2024). The methodology was based on the Knowledge Development Process-Constructivist type, namely ProKnow-C such as those reported by Costa et al. [5]. The databases used in this study were selected considering access to complete texts and their insertion in the environmental sciences and engineering areas: Web of Science and Scopus. For the searches, the combination of keywords used was: ("surface water" OR freshwater OR Reservoir) AND ("*in situ* treatment" OR "nature-based solutions" OR NBS OR "biochemical remediation") AND (Phosphorus AND nitrogen OR eutrophication) AND pilot scale.

Results and Discussion

A total of 2168 manuscripts were retrieved. After evaluating the adherence to the scope of the present work and excluding proceeding paper, early access, editorial material, book chapter, note, reprint and retracted publication, database was reduced to 272 papers.

The preliminary search using input keywords yielded intriguing results. Notably, terms such as "nitrogen", "freshwater", "performance", and "removal" emerged

with significant relevance. This highlights the growing research focus within the field of environmental science and engineering of the efficacy of NBS in removing nitrogen, a key nutrient contributing to eutrophication, from freshwater bodies. The high frequency of these terms within published manuscripts (both reviews and research articles) over the past decade (Figure 1) reinforces this observation.

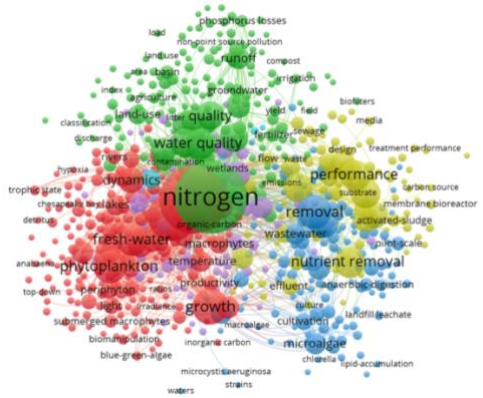

Figure 1. Map of keywords which were most present in the title, abstract, and keywords sections of all manuscripts (n = 2168) retrieved in the search after adherence stage of the methodology.

These findings underscore the growing recognition of NBS as a valuable approach for treating surface water from eutrophic ecosystems. Data showed that NBS offer a more sustainable alternative in contrast to conventional water treatment methods applied standalone. They leverage natural processes and materials, minimizing the environmental footprint associated with treatment. importance of NBS for eutrophic water treatment. Compared to conventional methods that often require high energy inputs and infrastructure development, NBS can potentially be more cost-effective in the long-term viability of the project, particularly for larger-scale applications. In addition, NBS can promote biodiversity by creating habitats for various aquatic organisms. This, in turn, contributes to a more balanced ecosystem that can naturally regulate nutrient levels and improve overall water quality.

The review of literature suggests potential applications for NBS that evolve constructed wetlands, which are engineered systems which mimic natural wetlands and can effectively remove nitrogen through various biological and physical processes. Bioremediation utilizing microorganisms that naturally break down nitrogenous compounds offers a promising biological approach within the NBS framework.

It is also important to note that *in-situ* solar photocatalysis technology has become a trending topic in water treatment, especially due to its environmental friendliness, and low energy consumption. Literature demonstrates that this approach can not only effectively treat persistent organic pollutants in water bodies, but also remove heavy metal ions and microorganisms, thus significantly improving water quality. Furthermore, the presence of organic and inorganic compounds in surface water can act as photosensitizers under solar irradiation aiming to degrade pollutants [6]. However, most research to date remains at the laboratory stage, and the application of *in-situ* photo-treatment in natural water bodies is still limited.

Conclusions

While the initial analysis suggests a growing body of research on NBS for treating eutrophic waters, the identified lack of full-scale applications necessitates further investigation: (i) Optimizing existing NBS designs for specific eutrophic water bodies and target pollutants; (ii) evaluating the long-term efficacy and cost-effectiveness of NBS compared to conventional methods; (iii) Developing detailed guidelines for implementing and maintaining NBS for water treatment applications; and (iv) Conducting pilot-scale studies to bridge the gap between theoretical potential and practical implementation of NBS solutions.

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References

[1] K. Javan, A. Altaee, S. BaniHashemi, M. Darestani, J. Zhou, G. Pignatta, *Science of the Total Environment*, 912 (2024) 169319.

[2] S.L. Akinnawo, *Environmental Challenges*. 12 (2023), 100733.

[3] N. Frantzeskaki, T. McPhearson, M. J., Collier, D. Kendal, H. Bulkeley, A. Dumitru, C. Walsh, K. Noble, E. van Wyk, C. Oke, L. Pintér, *BioScience,* 69 (2019), 455.

[4] H. Nesshöver, T. Assmuth, K.N. Irvine, G.M. Rusch, K.A. Waylen, B. Delbaere, D. Haase, J. Jones-Walters, H. Keune, E. Kovacs, K. Krauze, M. Külvik, F. Rey, J. van Dijk, O.I. Vistad, M.E. Wilkinson, H. Wittmer. *Science of the Total Environment,* 579 (2017), 1215.

[5] E.P. Costa, M.C.V.M. Starling, C.C. Amorim, *Environmental Science and Pollution Research,* 28 (2021), 24092.

[6] H. Xiong, H. Bao, F. Long, Y. Duo., J. Qu, Z. Luan, X. Sun. *Journal of Environmental Chemical Engineering,* 12, (2024).