The Use of Wetlands in Mining Pits as Sustainable Technology for Improving Water Quality in Rivers

Lisboa, L.S.*, Cubas, S.A.*, Troyan, G.R.**, and Maranho, L.T.*

*UFPR – Universidade Federal do Paraná, Curitiba, BR
**PUC - Pontifícia Universidade Católica do Paraná, Curitiba, BR

Highlights:

- Reutilization of mining areas for the preservation of water resources.
- Sustainable technology for the restoration of degraded aquatic ecosystems.
- Strategic use of wetlands for the restoration of degraded aquatic ecosystems.

Keywords: Sustainable technology; Wetlands; Water resources; Water quality.

INTRODUCTION

Since 1940, sand mining has been occurring along the banks of the Iguaçu River in the Greater Curitiba, reshaping the topography through the formation of pits. These, combined with increasing urbanization, have led to the degradation and pollution of the Iguaçu River due to the discharge of sewage from different sources, being considered the second most polluted river in Brazil (IBGE 2015) as it passes through the Greater Curitiba.

The water crisis in this region (Paraná 2020), and the deterioration of the water bodies' quality, led the Paraná Sanitation Company (Sanepar) to initiate studies to deal with the water challenges, adopting Nature based Solutions (NbS) to promote the conservation and restoration of water resources sustainably and effectively. The mining pits along the banks of the Iguaçu River are the main focus of these studies because over the years, these pits have accumulated water with nutrients, providing the macrophytes' development, forming wetlands (Comec 2013), which can be used to remove pollutants and store water (Ferreira *et al.* 2023). This research aims to assess the current condition of wetlands in a delimited study area, identifying macrophytes as part of the ecological succession process, and the necessary adaptations to use the system as a NbS, contributing to the restoration of the Iguaçu River's water quality.

METHODOLOGY

Besides the 5,000 ha of wetlands chosen by Sanepar, some specific pits were selected, as illustrated in Figure 1, with 198 ha. Historical cartography and satellite image database were used to estimate the period of sand mining, pit formation, and the mapping the process to get the pits' current condition.

The current mapping included aerial imaging by Unmanned Aerial Vehicle, followed by field visit where the macrophytes species were identified, as well as their biological forms by Irgang *et al.* (1984), which enabled compatibility with the product of digital processing of the aerial images and resulted in the representation of vegetation cover area.

Species identification was used to relate their biological form to water depth, based on wetland bathymetry and comparisons with the literature. Through the wetland water balance study by Hamirisi (2023) and a river hydrological analysis using data from Sanepar (2023), scenarios for wetland operation were created, considering periods of low and high flow rates and their impacts on hydraulic detention time.

RESULTS AND CONCLUSIONS

Mining reports and historical satellite imagery indicate that, in the absence of anthropogenic interference, pits take approximately 15 years to transition into wetlands. However, irregular settlements and the progression of river contamination accelerate the growth of aquatic macrophytes, which, in turn, improves water quality by removing pollutants essential for their development.

The integration of aerial images with field vegetation surveys facilitated the identification of the coverage area of the species with the highest coverage in the wetlands, as illustrated in Figure 1. What makes the use of aerial imagery a valuable tool for surveying and monitoring macrophytes in large areas is its ability to cover extensive regions efficiently.

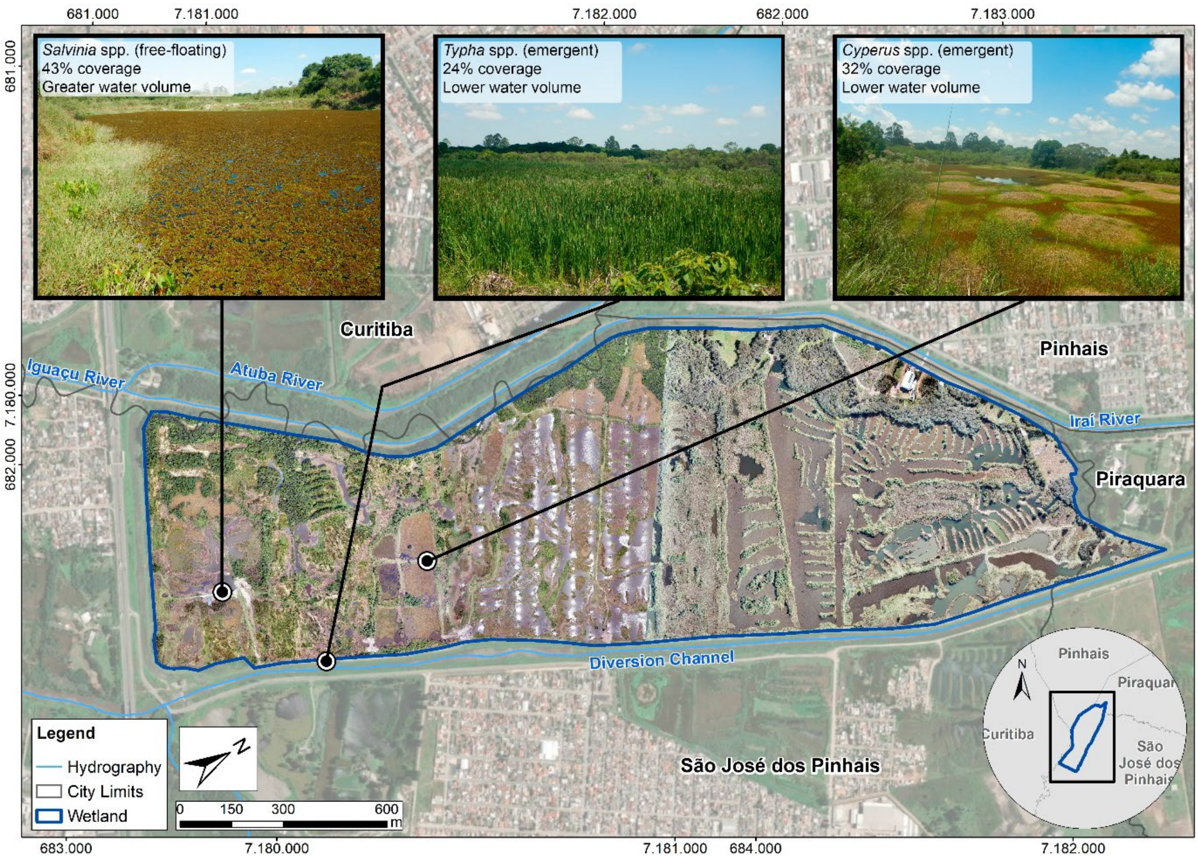

Figure 1: Study area and macrophytes georeferenced photos of largest coverage area

The results indicated that approximately 43% of the vegetation is composed of *Salvinia* spp. (free-floating), which, according to Pott and Pott (2003), can be associated with deeper areas, ranging from one to five meters, resulting in a higher water volume. In contrast, macrophytes with amphibious and emergent biological forms, such as *Typha* spp. (24%), according to Alves, Tavares, and Trevisan (2011), can be associated with areas of lower water volume, up to 0.30 meters.

However, *Cyperus* spp. (32%), an emergent macrophyte, was found growing over *Salvinia* spp., indicating an epiphytic behavior, that allows emergent vegetation to thrive even at greater depths. This type of vegetation behavior, along with the occasional presence of amphibious species in aquatic environments, suggests a subsequent stage in ecological succession, where the water accumulated in the pits has gradually been replaced by sedimentation and vegetation development.

Based on the characteristics of the wetland phytophysiognomy, *Salvinia* spp., *Cyperus* spp., and *Typha* spp., all exhibit potential for reducing organic matter through phytoremediation. According to Munfarida *et al*. (2020), Ariyachandra *et al.* (2023) and Haghnazar *et al*. (2023), these species are associated with the reduction of biochemical and chemical oxygen demand, nitrogen, phosphorus, and heavy metals.

The use of Unmanned Aerial Vehicles (UAVs) stands out as a technological innovation in the identification of macrophytes due to their practicality, speed, and coverage in large-scale areas. Additionally, UAVs enable the monitoring of vegetation development, species changes, and the optimal timing for management, thereby preventing the reintroduction of pollutants absorbed by macrophytes at the end of their life cycle.

A scenario favoring ecosystem preservation was modeled through the water balance of the wetland, where the system will operate from the 871-meter mark, allowing for a variation of 2.5 meters in height and 1,600,110 m³ in volume. By using only part of the wetland's water volume, it is possible to operate the system even in a drought scenario, replenishing 1/5 of the volume from the 95th percentile of the flow duration curve (0.3 m³/s), thus contributing to the dilution of the river with better-quality water.

The hydraulic detention time, calculated with half the flow from the 95th percentile of the flow duration curve (1.5 m³/s), and with a wetland of greater volumetric capacity (1,794,595 m³), is approximately 55 days. This is higher compared to similar natural wetlands near the study area, which are integrated into the treatment process for landfill leachate (Cavaleiro et al., 2014) and exceeds the hydraulic loading rate recommended for secondary treatment (Von Sperling; Sezerino, 2018).

Thus, by supplying river water to the wetlands through the natural connections identified during the site visit, along with the phytoremediation capabilities of the vegetation and adequate hydraulic detention time, it can be confirmed that the wetlands have the capacity to improve the river's water quality, even during extreme periods of both high and low river flow.

ACKNOWLEDGEMENTS

The data used in this research was derived from the Reservas Hídricas do Rio Iguaçu project, in cooperation between Universidade Livre do Meio Ambiente (UNILIVRE) and Paraná Sanitation Company (Sanepar).

REFERENCES

Construtora Hamirisi Ltda. (2023). *Estudo hidrológico do balanço hídrico e curva de permanência das cavas do Altíssimo Iguaçu. Curitiba*. [Tech. Rep.]. Curitiba.

Coordenação da Região Metropolitana de Curitiba (COMEC). (2013). *Elaboração de estudo de concepção do plano diretor da área de interesse especial regional do Iguaçu – AIERI*. [Tech. Rep.]. Curitiba.

Instituto Brasileiro de Geografia e Estatística (IBGE). (2015). *Indicadores de desenvolvimento sustentável: para Brasil*. Rio de Janeiro. pp.67.

Irgang, B., Pedralli, G., Waechter, J.L. (1984). *Macrófitas aquáticos da Estação Ecológica do Taim, Rio Grande do Sul, Brasil*. Roessléria 6.

Decreto nº 4.626 de 7 de maio de 2020. (2020). Decreta situação de emergência hídrica no Estado do Paraná pelo período de 180 dias. Diário Oficial Paraná, Curitiba, PR.

Companhia de Saneamento do Paraná (Sanepar). (2023). *MPS módulo 12.2 – Diretrizes para elaboração de estudo de disponibilidade hídrica de mananciais superficiais*. Curitiba.

Pott, V. J. & Pott, A. (2003). Dinâmica da vegetação aquática do Pantanal. In: Thomaz, S. M. & Bini, L. M. (Ed.). *Ecologia e manejo de macrófitas aquáticas*. Maringá: EDUEM.

Alves, J. A. A.; Tavares, A. S. & Trevisan, R. (2011). Composição e distribuição de macrófitas aquáticas na lagoa da Restinga do Massiambu, Área de Proteção Ambiental Entorno Costeiro, SC. *Rodriguésia*, 62 (4), 785-801.

Cavalheiro, T. L.; Amorim, A. M. P. B.; Preussler, K. H. & Maranho, L. T. (2014). Avaliação da eficiência das Wetlands Naturais no Pós-Tratamento do Lixiviado no Aterro Sanitário da Caximba, Curitiba, PR, Brasil. *Anais do Seminário Regional Sobre Gestão de Recursos Hídricos*. RJ, 4.

Von Sperling, M.; Sezerino, P. H. (2018). *Dimensionamento de wetlands construídos no Brasil.* Boletim Wetlands Brasil, Edição Especial, 65 p. ISSN 2359-0548.

Munfarida, I.; Auvaria, S. W.; Suprayogi, D. & Munir, M. (2020). Application of Salvinia molesta for water pollution treatment using phytoremediation batch system. *IOP Conference Series: Earth and Environmental Science*, 493 (1), p. 012002.

Ariyachandra, S.; Alwis, I. & Wimalasiri, E. (2023). Phytoremediation Potential of Heavy Metals by Cyperus rotundus. Reviews in *Agricultural Science*, 11, p. 20-35.

Haghnazar, H.; Sabbagh, K.; Johannesson, K. H.; Pourakbar, M. & Aghayani, E. (2023). Phytoremediation capability of Typha latifolia L. to uptake sediment toxic elements in the largest coastal wetland of the Persian Gulf. *Marine Pollution Bulletin*, 188, 114699.