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Approach for Wastewater Treatment Plants for Small Municipalities in Brazil: Achieving High Treatment Standards at Feasible Costs

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Highlights:

- **Efficient SBR treatment; effluent meets high standards with minimal maintenance**
- **Sludge Treatment Wetlands (STW) offers local complete cost-effective sludge treatment**
- **SBR-STW combination provides integral, economical wastewater treatment solution for small municipalities**

Keywords: Municipal WWTPs; Sequencing Batch Reactors (SBR); Sludge Treatment Wetlands (STW).

INTRODUCTION

With Brazil's ambitious plan for Universalization of Urban Sanitation until 2033, investments in wastewater treatment plants (WWTP) for smaller municipalities are gaining momentum. This urgency is starkly evident as 80% of Brazil's municipalities have populations under 30,000 inhabitants, facing pressing sanitation needs, as highlighted by the national survey (Atlas Esgotos, 2017) and even in large urban centers, decentralized solutions often represent the most viable option.

Smaller or decentralized WWTPs in Brazil, typically handling up to 30 L/s, encounter unique challenges. On one hand, technical simplification, often pursued for cost-saving reasons, leads to increased manual labor and operational control issues. On the other hand, smaller and consequently more uniform wastewater catchment areas are usually characterized by much higher relative fluctuations in wastewater volume and composition than the regulations, primarily designed for larger plants, account for (Platzer et al., 2016). Despite these challenges, smaller WWTPs are often expected to meet stringent regulatory limits, sometimes even surpassing those imposed on larger WWTPs.

In addition, decentralized WWTPs also grapple with the necessity of continuous treatment and disposal of sludge, adding to operational complexity and operational costs. From an economic perspective, sludge management traditionally represents a considerable portion of the operational costs of a WWTP, typically between 20% and 60% (Andreoli et al., 2007; Uggetti et al., 2010). For smaller and for more remote municipalities, these costs tend to fall on the higher end of the spectrum due to longer distances.

Against this backdrop, this paper scrutinizes the operational performance of a WWTP in Paraná, Brazil, serving a municipality of 15,000 inhabitants, equipped with two SBR reactors and a sludge treatment wetland (STW), for complete local surplus sludge treatment from SBR.

METHODOLOGY, DESCRIPTION OF THE WWTP

The WWTP in Santa Helena, Paraná, Brazil, commenced operation in December 2019 with the capacity to treat 30 L/s of wastewater, with maximum peaks reaching 45 L/s. The WWTP was constructed on the site of a pond system (Figure 1) that no longer met the necessary treatment requirements.

To address this, 2 Sequencing Batch Reactors (SBRs) were installed for biological treatment, and the existing maturation pond was repurposed into a Sludge Treatment Wetland (STW) for dewatering and mineralization of the SBR surplus sludge (figure 1).

Figure 1: Aerial view of Santa Helena WWTP showing 2 SBR reactors and Sludge Treatment Wetlands divided into 12 separate beds, installed in the former maturation pond.

As demonstrated by the schematic plant layout (Figure 2), preliminary effluent treatment involves an automatically cleaned bar screen followed by a grit chamber. The effluent then undergoes biological treatment in two parallel SBR reactors (activated sludge/extended aeration). Each SBR operates three treatment cycles per day, which are controlled automatically. At the end of each cycle, the treated effluent is discharged, and excess sludge is automatically removed and pumped directly to the STW.

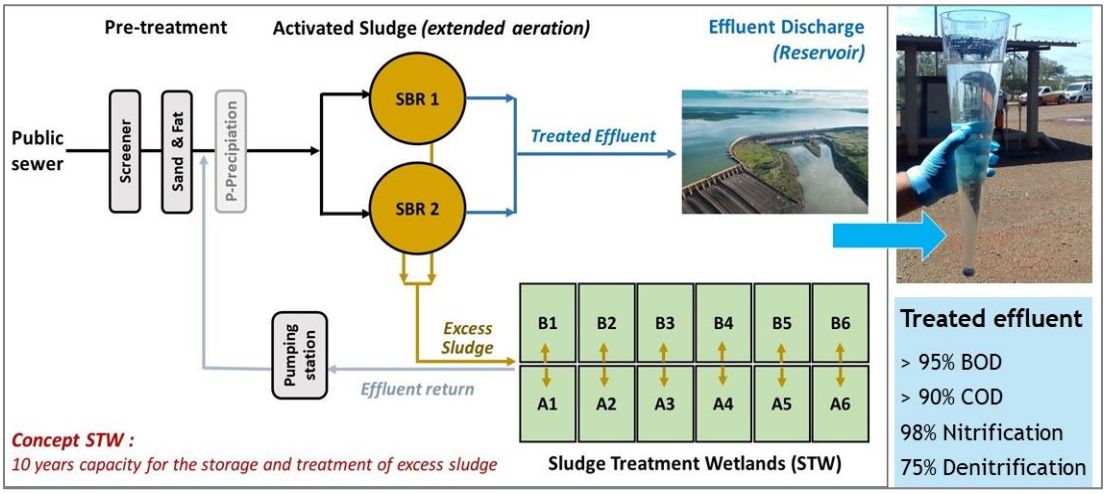

Figure 2: Santa Helena WWTP Layout with photo of treated effluent and efficiency parameter.

The STW has a surface area of 4,334 m², divided into 12 beds and planted with 3 species of macrophytes native to Brazil: *Typha domingensis*, *Cyperus giganteus* and *Hymenanche grumosa*. The drainage system at the bottom of each bed is covered by 20 cm of gravel and 20 cm of coarse sand. The remaining fill height of 180 cm was designed to accommodate a sludge load of 40 to 60 kg ST/m² per year over a period of 10 years, in line with previous international experience (Nielsen, 2005) and its adaptation to warm climate conditions (Hoffmann et al., 2021; Platzer et al., 2023).

RESULTS AND CONCLUSIONS

During first 5 years of operation the SBR treated effluent consistently meets very high treatment standards, achieving more than 90% COD and 95% BOD removal, along with 98% Nitrification and 75% Denitrification (figure 2), demonstrating high stability and minimal maintenance requirements, with optimized energy consumption. SBR cycle times, as well as the duration of aerobic and anoxic cycles, are automatically adjusted based on sensors such as level sensors and oxygen probes, to adapt to varying wastewater flow rates and loads.

The introduction of the Sludge Treatment Wetland (STW) represents a pioneering nature-based solution for sludge treatment in Paraná. The annual field monitoring, conducted most recently after 52 months of operation (Figure 3), indicates a notably efficient sludge stabilization process, with an average sludge accumulation of just 7.5 cm per year (Figure 4). Even when accounting for a potential maximum increase of 10 to 12 cm per year, due to increased sewer maintenance and additional sludge from chemical phosphorus removal, this would still allow for an extended storage period of around 20 years before the removal of dry mineralized sludge or humus becomes necessary for the first time.

Figure 3: Sample of the sludge deposited during the first 52 months.

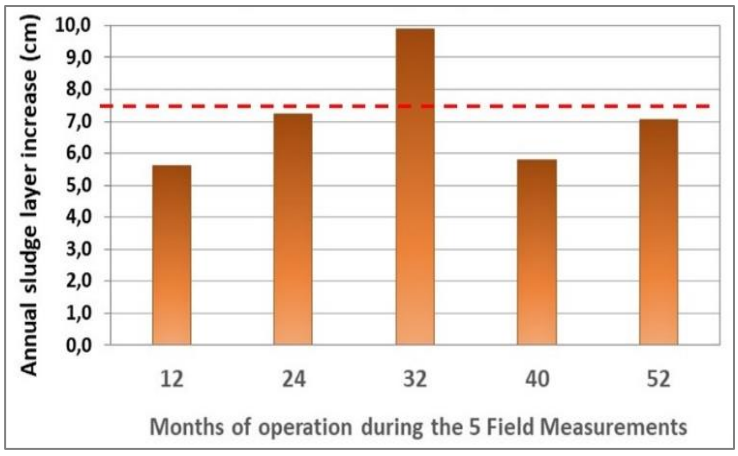

Figure 4: Results of Sludge treatment Wetland, average annual sludge layer growth rate.

The Sludge Treatment Wetland (STW) has clearly proven to be a key component in making efficient wastewater treatment viable, even for smaller and remote municipalities that have enough area for its implementation. It offers an economical solution for complete local sludge treatment with minimal maintenance costs, providing a fourfold (4.06) reduction in present value compared to mechanical sludge treatment (Hoffmann et al., 2022). Notably, the potential for sludge reuse, updated in Brazil under CONAMA 498/2020, has not yet been considered.

In summary, the combination of a Sequencing Batch Reactor (SBR) with STW has proven to be a sustainable and efficient solution, particularly for absorbing the highly variable wastewater volumes typical of smaller treatment plants (Platzer et. al, 2016). This approach allows municipalities to meet the highest standards for both effluent and sludge treatment with feasible operational costs. Demand-driven automation and energy-efficient operations ensure continuous monitoring, without requiring the constant presence of an operator, while also opening up new possibilities for advanced remote control.

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