Engineered Ecosystem applied to decentralized domestic wastewater treatment on Ilha Grande, RJ - Brazil: 14 years of monitoring

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Highlights:

- Even after 14 years of operation of the Engineered Ecosystem, it maintained efficiency in the treatment of domestic effluents.
- Domestic wastewater treatment systems that involve nature-based solutions have great potential to be adopted in isolated or rural areas.
- Ensuring the best aerobic conditions is essential for greater removal and/or incorporation of nitrogen into the biomass of vegetated tanks.

Keywords: On-site wastewater treatment; Isolated areas; Nature-based solutions

INTRODUCTION

The adoption of novel strategies to enhance the coverage of wastewater treatment services is imperative (Capodaglio et al., 2017). Nature-based solutions is increasingly acknowledged as a pivotal avenue for tackling the intricate challenges of water and wastewater management while ensuring satisfactory treatment outcomes (Castellar et al., 2022; A. Pascual, 2023).

Engineered Ecosystems (EE) combine conventional wastewater treatment methodologies such as septic tanks and submerged aerated filters with supporting infrastructure, alongside mixed biofiltration, incorporating constructed wetlands (Kavanagh; Keller, 2007; Salomão et al., 2012). This integration fosters a more comprehensive and efficient treatment approach by encompassing all three treatment stages (primary, secondary, and tertiary) within a unified system.

The aim of this study was to present a 14-year monitoring program with focus on the performance of a decentralized domestic wastewater treatment system located in an isolated area in Vila Dois Rios, Ilha Grande/RJ.

METHODOLOGY

The Engineered Ecosystem (EE) is a compact, full-scale system that has been operating since 2009 in a tropical region to treat an average flow of 1248 L day-1 of wastewater generated at the Center for Environmental Studies and Sustainable Development (CEADS), a research campus of the Rio de Janeiro State University (UERJ), located in Vila Dois Rios, Ilha Grande, Angra dos Reis Municipality, Rio de Janeiro State/Brazil (Salomão et al., 2012).

The entire treatment plant occupied 25 m² (**Figure 1**), including an upflow septic tank (ST), a submerged aerated filter (SAF), a mixed biofilter (MBF), an algae tank (AT) and three constructed wetlands with horizontal flow (CW). The CW1 with a surface flow a hosts the macrophyte *Eichhornia crassipes* (Pontederiaceae); the CW2 with a subsurface flow hosts the *Typha domingensis* (Typhaceae); the CW3 with a subsurface flow was colonized by different grasses.

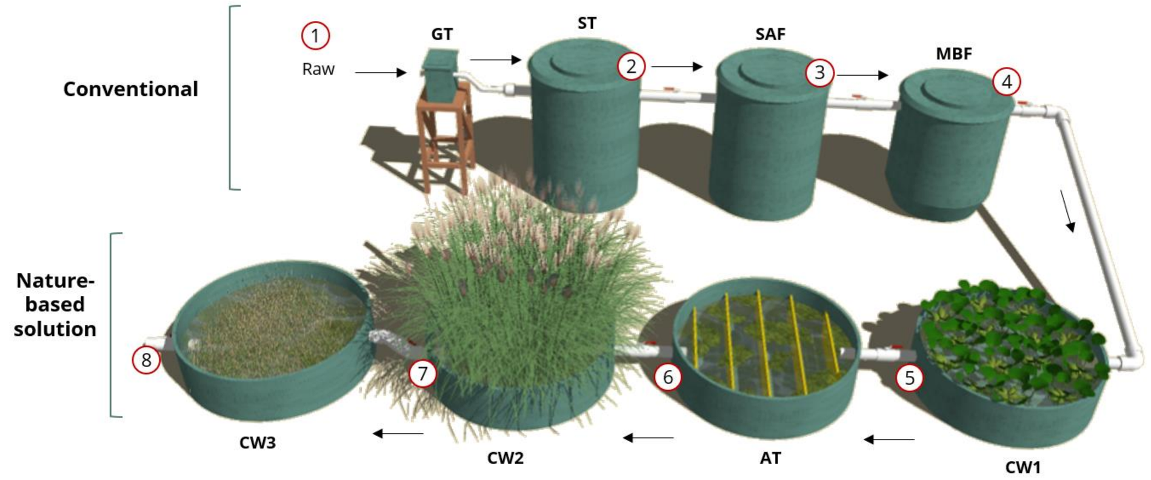

Figure 1 – Diagram and image of an Engineered Ecosystem (EE).

During the 14 years of operation, the EE underwent different monthly monitoring periods. In this investigation, two cycles were evaluated: from 2009 to 2011 (Cycle 1), initial operating and monitoring period, and from 2022 to 2023 (Cycle 2), most recent operating and monitoring period. Sampling points included the influent (raw wastewater) and the effluent at the end of each tank.

The following parameters were analyzed in the laboratory: Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), ammonium, nitrate, nitrite, total nitrogen (TN) and total phosphorus (TP) according to APHA (2017). Temperature, pH, oxidation-reduction potential (ORP), Total Dissolved Solids (TDS) and dissolved oxygen (DO) were determined *in situ* using portable probe (APHA, 2017).

RESULTS AND CONCLUSIONS

Table 1 shows that the EE's global performance in both cycles is comparable to that one achieved by similar full-scale systems, excluding nitrogen removal (Rout et al., 2021). The discharge from the final CW was always colorless and odorless.

Parameters	Influent	Effluent	Average removal efficiency	Influent	Effluent	Average removal efficiency
	cycle 1 [a]			cycle 2 [b]		
COD (mg L^{-1})	661±216	78±63	88%	529±140	137±67	74%
TSS (mg L^{-1})	288±155	17±23	94%	138±73	17±31	88%
TDS (mg L^{-1})	397±250	359±161	10%	544±383	289±211	47%
pH	6,7±0,3	6,7±0,3	-	6,4±0,7	6,5±0,5	-
ORP (mV)	-10±73	7,8±33	-	-109±81,3	74±94,5	-
T (ºC)	24±3	22±3	-	25±4	25±3	-
TP (mg L^{-1})	38±27	19±10	50%	15±4	18±4	-20%
TN (mg L^{-1})	78 ± 57	53 ± 45	32%	34 ± 7	32 ± 20	7%

a :n = 19
b :n = 11

Table 1 – Average ± standard deviation values in influent (raw) and effluent (final) of EE

In Cycle 1, the EE performed better for all parameters when compared to Cycle 2, except for TDS. It had a constant efficiency for the COD and TSS parameters of 88% and 94% in Cycle 1, and 74% and 88% in Cycle 2, respectively. This higher efficiency in the first 3 years of operation (Cycle 1) was due to the fact maintenance was carried out more frequently (Salomão et al, 2012). Furthermore, initially the system did not present problems regarding clogging and saturation in the CWs, as expected (Kadlec & Wallace, 2008). However, the instability of the average flow influenced the removal of TDS. During the last years of operation, the system was kept for a long period without maintenance due to the pandemic Covid-19.

Regarding nutrients, during Cycle 1 it was observed higher removal efficiency, with 50% removal of TP and 32% TN, while during Cycle 2, an increase in phosphorus and only 3% removal of TN were registered. The best performance in Cycle 1 was probably due to the greater absorption of TP by the filter medium and the FAS had aeration within the expected values for nitrification. However, the following tanks did not present suitable conditions for denitrification in both cycles. Power surges were frequent, given the implementation of the system in isolated areas, which compromised the efficiency of TN removal due to failures in the aeration system (Daskiran et al., 2022).

After 14 years of operation, the EE performance has remained high in the reduction of COD and TSS, proving that EE technology works, besides the low operational costs, relatively simple maintenance, and no addition of chemical products (Vymazal, 2022). However, to increase nutrients removal, it is necessary to improve the aeration system to guarantee the best treatment conditions (Miyazaki et al., 2023). Finally, EE demonstrated to be a feasible and suitable option to be areas applied under similar conditions.

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