EVALUATION OF A PILOT TEST WITH COMPACT ULTRAFILTRATION TECHNOLOGY TO PRODUCE REUSABLE WATER IN A SEWAGE TREATMENT PLANT WITH TERTIARY TREATMENT

Marinheiro, L.*, Ramos Junior, W.*, Lippi, M.*, Chataque, M.**, Lermontov, A.**

* AST – Serviços, Soluções e Tecnologia em Meio Ambiente S/A, Rua Madre Maria Victória, 90 - salas 803/804 - Charitas, Niterói – RJ, 24.370-035 – Brasil
** Grupo Águas do Brasil, Av. Marquês do Paraná, 110 - Centro, Niterói - RJ, 24.030-211, Brasil

Highlights:

- Water resources encounter increasing demands attributed to population growth and industrial expansion.
- Membrane separation processes are widely applied for water treatment with growing implementation for water reuse purposes.
- This study assessed the performance of an ultrafiltration (UF) pilot employed as quaternary treatment in a Wastewater Treatment Plant.
- The UF permeate exhibited quality compatible with Class B criteria in Brazilian and European legislation for restricted urban use.

Keywords: Ultrafiltration; Water Reuse; Wastewater Treatment Plant

INTRODUCTION

Water resources are facing increasing demand due to population growth and industrial expansion. Industries have proactively sought solutions to address mounting water demands by turning to effluent reuse as a viable alternative to mitigate the challenges of water scarcity. This approach has proven effective in reducing overall water demand.

In this context, Membrane Separation Processes (MSP) have been widely applied, particularly within existing effluent treatment systems as a pivotal post-treatment stage. Notably, among MSPs, ultrafiltration membranes (UF) gained attention. In recent years, owing to their capacity to remove high molecular weight compounds, suspended solids, viruses, and bacteria, UF membranes have been prominently utilized in the construction of Membrane Bioreactor (MBR) projects (Branch et al., 2021). Additionally, UF membranes have been employed in post-treatment applications for water and effluents, producing superior-quality water suitable for reuse (Clem & De Mendonça, 2022; Aani et al., 2020).

Against this backdrop, the present study assesses the operational efficacy of a pilot ultrafiltration (UF) unit. The UF unit functions as a quaternary treatment after the floater at the initial stage and assumes the role of tertiary treatment at the subsequent stage following the secondary decanter within the activated sludge system at the Wastewater Treatment Plant (WTP) located in Camboinhas, Niterói, in the state of Rio de Janeiro.

METHODOLOGY

An UF pilot unit was used as a quaternary treatment stage, processing part of the treated effluent from a flotation system installed at Camboinhas WTP as a tertiary treatment step. The flotation unit receives a secondary treated effluent produced through an Upflow Anaerobic Sludge Blanket (UASB) Reactor followed by an Integrated Fixed-film Activated Sludge (IFAS).

In this pilot test, a submerged hollow fiber filtration cartridge was used. The cartridge comprises a polyethene (PE) hollow fiber membrane of 1600-2000 fibers with a nominal pore size of 21 nm, providing a membrane area of around 6 m². The model used, named SMART-MEM, was supplied by AQUASMART – Water and Wastewater Treatment Solutions and operates in an outside-in membrane configuration. The cartridge integrates two inlets: an upper one for permeate output and a lower one for air injection during backwashing procedures.

The system layout encompasses an inlet tank and a separate tank designated for accumulating treated effluent, known as the permeate tank (Figure 1). The pilot test was conducted over 8 working days, with an operational period of approximately 8 hours per day. Daily collections of both incoming effluent and permeate were conducted throughout this phase. The samples obtained underwent characterization in an external laboratory, utilizing established methodologies outlined in Standard Methods (APHA, 2017), in order to quantify various parameters. Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Escherichia coli, Turbidity, and Total Phosphorus (TP), analyzed via ICP-MS using EPA 6020 B/200.8 protocols.

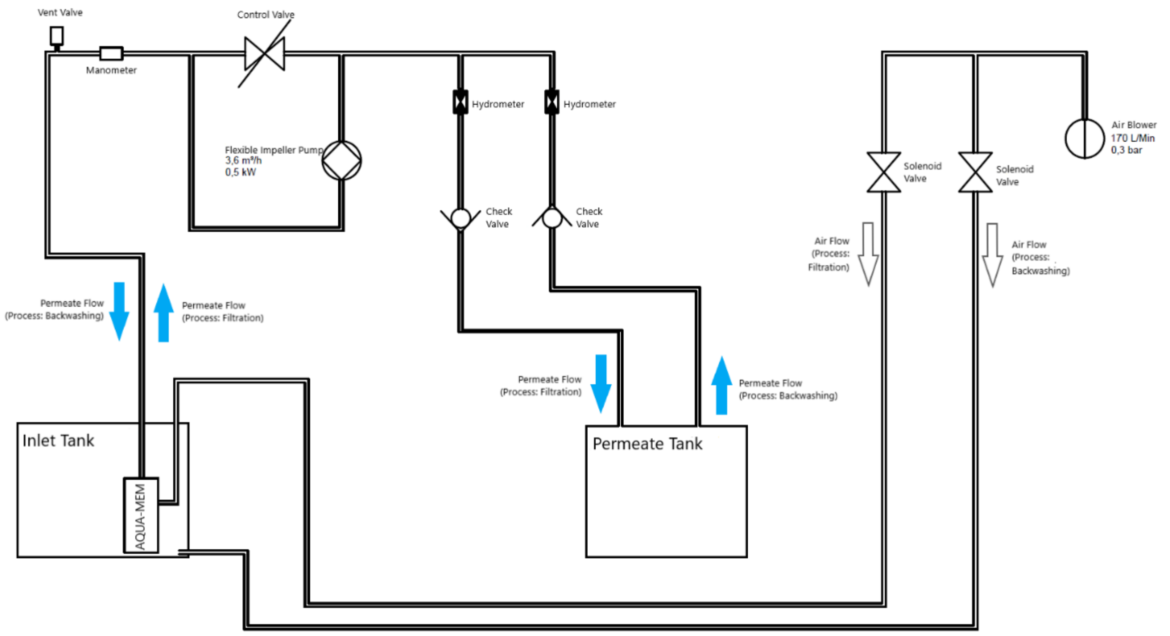

Figure 1 - UF Pilot Process Flowchart

RESULTS AND CONCLUSIONS

Table 1 presents the average and standard deviation of the results of the test comparing with the standards established for reuse by the Government of the State of São Paulo (Joint Resolution SES/SIMA Nº 01/2020), the European Parliament (Regulation (EU) 2020/741) and by the Agency United States Environmental Protection Agency (EPA/600/R-12/618).

Table 3 - Comparison of results with national and international criteria for reuse

Parameters	Input		Output		SP[1]		UE[2]				USEPA[3]	
	Average	SD[4]	Average	SD[4]	Class A	Class B	Class A	Class B	Class C	Class D	Urban Unrest.	Urban Rstd.
BOD_5(mg/l)	13	4.8	10	4.3	≤ 10	≤ 30	≤ 10	25	25	25	≤ 10	≤ 30
COD (mg/l)	21	6.5	18	5.1	-	-	-	-	-	-	-	-
TSS (mg/l)	19	8.0	1.1	0.5	≤ 0.5	≤ 30	≤ 10	35	35	35	-	≤ 30
TP (mg/l)	0.44	0.3	0.04	0.03	-	-	-	-	-	-	-	-
E. coli (MPN/100ml)	60,375	50,568	207	64.0	ND[5]	≤ 120	≤ 10	≤ 100	≤ 1,000	≤ 10,000	ND[5]	≤ 200
Turbidity (NTU)	5	2.7	0.2	0.1	≤ 2	-	≤5	-	-	-	≤ 2	-
pH	6.8	0.2	7	0.2	6-9	6-9	-	-	-	-	6-9	6-9
EC (µS/cm)	701	125.3	700	115.1	≤ 700	≤ 3000	-	-	-	-	-	-

1 - SP: São Paulo – Joint Resolution SES/SIMA Nº 01/2020
2 - EU: European Union
3 - USEPA: United States Environmental Protection Agency
4 - SD: Standard Deviation
5 - ND: Not Detected

Considering the results of the first stage and the values of the minimum requirements for reuse of the Table 3, it is initially noted that the treated effluent (permeate) can be classified as Class B (for restricted uses), according to the standards of São Paulo and the European Union legislations, and as restricted urban use according to the USA legislation. The permeate failed to reach Class A (and unrestricted urban use) in all reference standards of this study due to two parameters, namely, TSS and E. coli.

In 62.5% of the results, the UF membrane permeate achieved values below the detection limit of the TSS method (0.8 mg/l). This value is marginally higher than the minimum requirement specified by São Paulo legislation (≤ 0.5 mg/l), the most stringent of the three standards evaluated. The observed E. coli results may be attributed to contamination during sample collection, particularly considering findings from other studies (Falsanisi et al., 2010; Arévalo et al., 2012; Yang et al., 2021). Therefore, although the average was higher in these two aspects, but considering the issues listed above, it can be considered that the water produced by the pilot, reaches the Class A classification, even without an associated disinfection system.

The results indicate that the pilot unit system with SMART-MEM membranes is a viable and interesting alternative for application in WTPs aiming to produce reused water for urban purposes, demonstrating promising operational efficiency and effectiveness.

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REFERENCES

Branch, A., Trinh, T., Ta, T. M., Leslie, G., & Le-Clech, P. (2021). Log removal values in membrane bioreactors: Correlation of surrogate monitoring and operational parameters. *Journal of Water Process Engineering*, *41*, 102032. https://doi.org/10.1016/j.jwpe.2021.102032

Clem, V., & De Mendonça, H. V. (2022). Ozone reactor combined with ultrafiltration membrane: A new tertiary wastewater treatment system for reuse purpose. *Journal of Environmental Management*, *315*, 115166. https://doi.org/10.1016/j.jenvman.2022.115166

Aani, S. A., Mustafa, T. N., & Hilal, N. (2020). Ultrafiltration membranes for wastewater and water process engineering: A comprehensive statistical review over the past decade. *Journal of Water Process Engineering*, *35*, 101241. https://doi.org/10.1016/j.jwpe.2020.101241

EPA Method 6020B (SW-846): Inductively coupled Plasma - Mass spectrometry | US EPA. (2024, May 7). US EPA. https://www.epa.gov/esam/epa-method-6020b-sw-846-inductively-coupled-plasma-mass-spectrometry

APHA (2017). *Standard Methods for the Examination of Water and Wastewater* (23rd ed.). Washington DC: American Public Health Association.

Joint Resolution of São Paulo State Department of Health / Department of Infrastructure and Environment (SES/SIMA) nº 1/2020 (2020). Regulates the direct non-potable reuse of water for urban purposes from Wastewater Treatment Plants and provides related measures. São Paulo, SP.

Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 (2020). On minimum requirements for water reuse. Brussels, Belgium.

EPA/600/R-12/618 Guidelines for water reuse (2012). United States Environmental Protection Agency (USEPA). Washington, D.C.

Falsanisi, D., Liberti, L., & Notarnicola, M. (2010). Ultrafiltration (UF) Pilot plant for municipal wastewater reuse in agriculture: Impact of the operation mode on process performance. *Water*, *2*(4), 872–885. https://doi.org/10.3390/w2040872

Arévalo, J., Ruiz, L., Parada-Albarracín, J., González-Pérez, D., Pérez, J., Moreno, B., & Gómez, M. (2012). Wastewater reuse after treatment by MBR. Microfiltration or ultrafiltration? *Desalination*, *299*, 22–27. https://doi.org/10.1016/j.desal.2012.05.008

Yang, J., Monnot, M., Eljaddi, T., Ercolei, L., Simonian, L., & Moulin, P. (2021). Ultrafiltration as tertiary treatment for municipal wastewater reuse. *Separation and Purification Technology*, *272*, 118921. https://doi.org/10.1016/j.seppur.2021.118921