FGKD24
Fourth-Generation Knowledge Districts 2024
20-21 May 2024, Campinas, SP

REVERSE OSMOSE EFFLUENT AS AN ALTERNATIVE FOR AIR CONDITIONING IN TECHNOLOGY PARKS

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Abstract. Fourth-generation technology parks prioritize the sustainable use of resources. Consequently, the evaluation of treatment effluent for Reverse Osmosis (RO) as an alternative for air conditioning systems was undertaken. To achieve this objective, the methodology focused on assessing parameters such as Chemical Oxygen Demand (COD), both total and soluble, Total Suspended Solids (TSS), Turbidity, and pH. These parameters were chosen to ensure the quality and suitability of the treated effluent for reuse in the air conditioning alimentation system, aligning with the overarching goal of resource sustainability within technology park environments, and the standards achieved with literature review. The results indicated that the treatment effluent met the necessary requirements for the analysed parameters, as supported by literature review. However, it is essential to further evaluate factors such as energy consumption and additional parameters to comprehensively assess the feasibility and sustainability of this approach.

Keywords: water reuse, urban fringe, decentralised system, SDG, resource management.

1 Introduction

Technology parks encompass a diverse array of companies co-located within a designated area, with the overarching objective of fostering the progression of science, technology, and innovation. They also seek to forge formal collaborations with universities, research centers, and other institutions of higher education (Salvador et al., 2019). Consequently, there is an emphasis on the adoption of sustainable practices aimed at bolstering energy efficiency and environmental management among these enterprises (Salvador & Silva, 2016).

Amid the escalation challenge of water scarcity, the incorporation of sustainable water reuse policies has become an integral component of corporate social responsibility (Den et al., 2018). As proposed by Sousa et al. (2023), a fourth generation of technology parks is emerging as an evolution from second-generation suburban science parks, underpinned by the quintuple helix framework. This paradigm facilitates the dispersion of capabilities across government, academia, and industry sectors. Notably, one of the helices is dedicated to the environment, recognizing it as a crucial new the utilization of both renewable and non-renewable natural resources (De la Vega Hernández & Barcellos de Paula, 2019).

To regulate indoor temperature, air conditioning systems are extensively employed globally. Nevertheless, this utilization carries substantial implications for water and energy consumption, especially for air dehumidification, particularly in regions characterized by water scarcity and predominantly hot climates (Luqman & Al-Ansari, 2021). Depending on the water efficiency rating of an evaporative cooler and the prevailing local climate conditions, water consumption for cooling a building can vary from 450 to 850 litters per day (Sahai, 2012; Sahai et al., 2012), which further escalation in buildings experiencing high occupancy rates.

Yan et al. (2010) undertook pilot–scale research investigating the use of ultrafiltration (UF) followed by reverse osmosis (RO) to treat the blowdown, which refers to the concentrated cooling water discharged by cooling towers, with the aim of reintroducing it into the cooling system. This methodology proved crucial for mitigating the membrane fouling in RO system (Wolf et al., 2005).

Drawing from the aforementioned considerations, this article aims to evaluate the effluent generated through the integration of a Membrane Bioreactor (MBR) and RO in an actual Wastewater Treatment Plant (WWTP) designed for application in air conditioning systems within technology parks. It's crucial to emphasize that the novelty of the article lies in expanding research on fourth-generation technology parks and the quintuple helix framework, particularly focusing on sustainable approaches. Currently, research in this area lacks a focus on wastewater reuse.

2 Methodology

In this assessment, the real WWTP being examined adheres to the layout outlined in Figure 1. It's crucial to highlight that the WWTP's location, where the samples were procured, is positioned in an area necessitating a decentralised system, resembling those found in technology parks situated on the urban fringe. Samples for analysis were gathered subsequent to the preliminary treatment, which includes a 2mm bar screen, and at three successive stages: pre-MBR (I), post-MBR treatment (II), and post-RO (III).

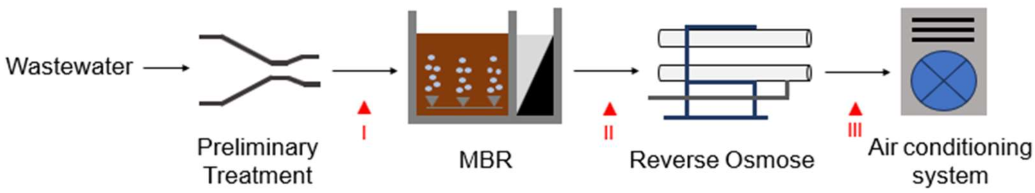

Figure 1. Schematic diagram of the WWTP. Source: Currently Article.

The sampling period extended from April and October, totalling 42 samples, with 14 collected from each of the stages I, II, and III. The parameters analysed included organic material, characterized in terms of Chemical Oxygen Demand (COD) both total and soluble, Total Suspended Solids (TSS), Turbidity and pH, following the recommended protocols outlined in the Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 2017). Analysis of the samples was conducted at the Sanitation Laboratory (LabSan) within the Faculty of Civil Engineering, Architecture, and Urbanism at the State University of Campinas. The resulting values underwent assessment via the Shapiro-Wilk normality test using The jamovi project (2023).

Finally, guidelines and legislations were referenced for comparative analysis. In the Brazilian context, Regulatory Standard N13 delineates the minimum requisites for managing the structural integrity of boilers, pressure vessels, their interconnecting pipes and metal tanks (N13 - Caldeiras, Vasos de Pressão, Tubulações e Tanques Metálicos de Armazenamento, 2022). This standard primarily emphasizes compliance with equipment specifications. Additionally, NBR 13969 specifies solely the minimum concentrations for agricultural reuse (ABNT, 1997).

In the United State of America, the Guidelines for Water Reuse defines the minimum parameters for recirculation cooling systems as follows: pH between 6.0 and 9.0, organic matter in terms of Biological Oxigen Demand (BOD) less than 30mg/L, TSS less than 30mg/L, fecal coliform less than 200MPN/100ml and chlorine residual lees than 1mg/L (Guidelines for Water Reuse, 2012).

The European Union also establishes minimum concentrations for agricultural reuse (Regulation (EU) 2020/741, 2020). Spain, specifically, has a Royal Decree outlining water quality indicator parameters for cooling towers and evaporative condensers. These parameters include a pH range between 6.5 and 9.0, Turbidity less than 15 Nephelometride Formacin Units (NFU) and Total Iron less than 2mg/L, with conductivity ensuring the water cannot have extremely fouling or corrosive characteristics. Additionally, biocide level must adhere to manufacturer’s specifications (Royal Decree 861/2003, 2003).

3 Results and Discussion

Following the Methodology, the results of the normality test indicated that the samples did not conform to a normal distribution. Consequently, the results will be represented using boxplot graphics. Therefore, Figure 2 presents the outcomes for turbidity at the three collection points.

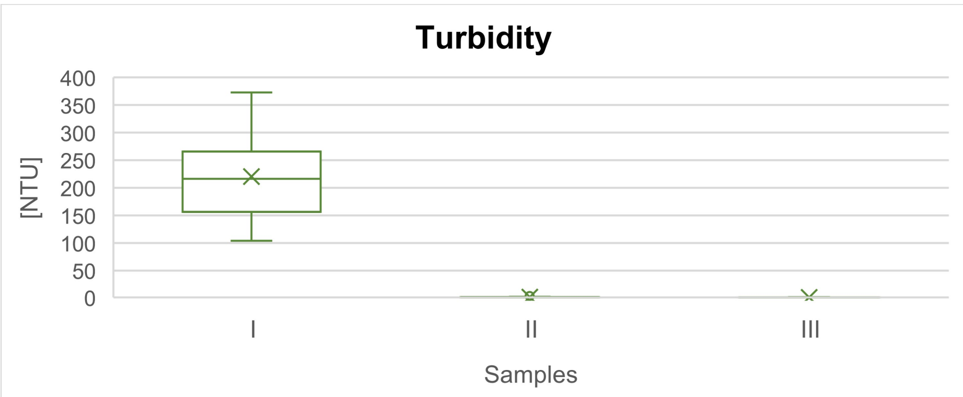

Figure 2. Turbidity results for the three points. Source: Currently Article.

The decrease in turbidity indicates that a significant proportion of solid particles in the influent are retained between the stages of the WWTP. The median turbidity for point I is approximately 216±82 NTU, whereas for points II and III, it approaches 0 NTU. This observation is consistent with the findings of Hosseinkhani & Kargari (2022), who highlighted that membrane treatment can reduce turbidity to <0.1 NTU, effectively eliminating colloids, dissolved organic and inorganic compounds associated with particles, as well as primary pathogens and contaminants. In contrast to the legislation outlined in methodology section, the turbidity standard in Spain mandates a level lower than 15NTU, as indicates by the medians for points II and III.

Regarding Total Suspended Solids, the mean values for point I were 656±1206mg/L for Total Suspend Solids (TSS), 48±127mg/L for Fixed Suspend Solids (FSS) and 613±1114 mg/L for Volatile Suspend Solids (VSS). For points II and III, the results were recorded as zero for Total, Fixed and Volatile Suspend Solids, and thus were not represented in a boxplot. When comparing the achieved standards, the TSS parameter, which must be less than 30mg/L (Guidelines for Water Reuse, 2012), is indeed met by samples collected from points II and III.

Figure 3 illustrates the results for pH at the three collection points.

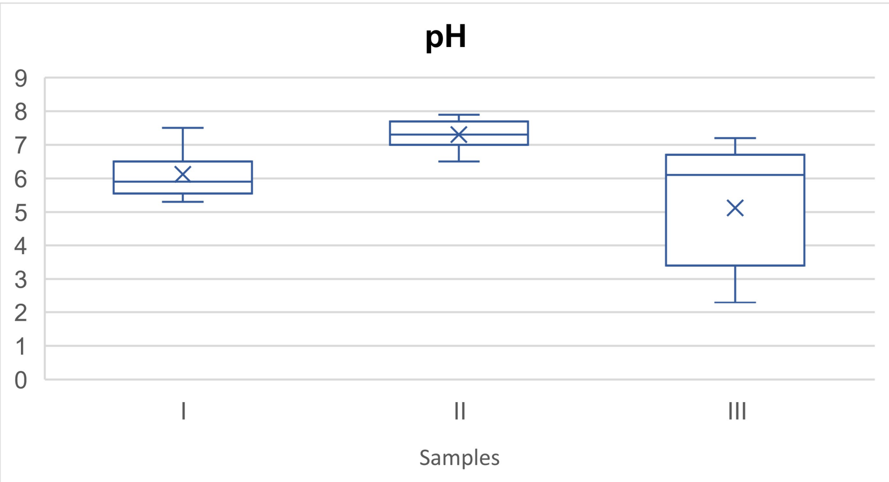

Figure 3. pH results for the three points. Source: Currently Article**.**

In terms of pH, the median at point I is 6.0±0.6, while at point II it is closer to 7.5±0.4, and at point III it is 6.0±1.77. It is notable that the variation in pH at point III is considerable, with the minimum value nearing 2.0 and the maximum slightly above 7.0. In some instances, this variability necessitates pH correction to prevent corrosion in air conditioning tubes. As pH increases, the concentration of hydrogen ions in solution decreases, facilitating the formation of a protective layer on metal surfaces and consequently increasing the anti-corrosion rate.(Li et al., 2017). According to Guidelines for Water Reuse and Royal Decree 861/2003, the pH range should ideally fall between 6.0 and 9.0 and 6.5 and 9.0, respectively. Therefore, in certain instances, it may be necessary to adjust the samples from point III to ensure they fall within the acceptable pH range, reaching a minimum of 6.0.

Figure 4 displays the results for organic matter in terms of Total and Soluble COD for the three points analysed.

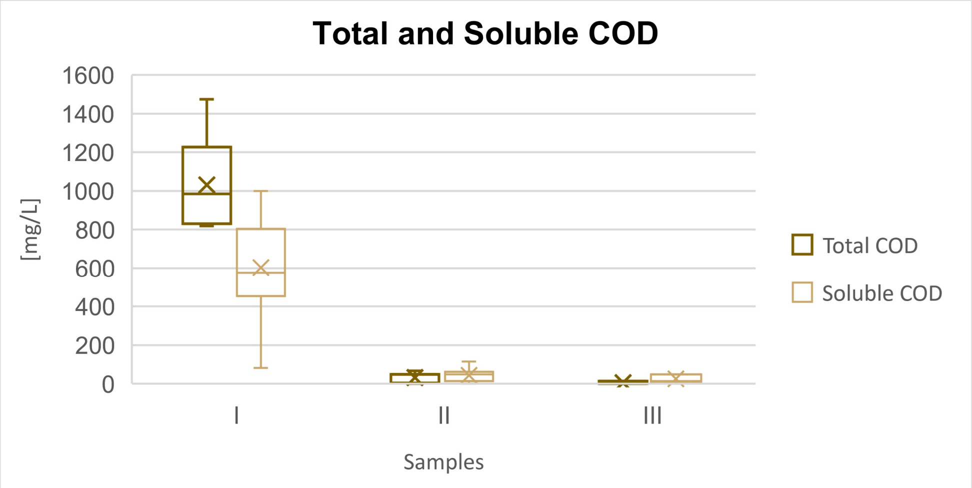

Figure 4. Total and Soluble COD results for the three points. Source: Currently Article**.**

The median results for organic matter in terms of Total COD were 954±211, 48±25 and 0±7 mg/L, for the samples I, II and III, respectively. For organic matter in terms of Soluble COD, the results for samples I, II and III were 577±249, 48±33 and 14±21mg/L, respectively. When compared to the standards, the requirement for organic matter is indicated by BOD levels less than 30mg/L.

BOD represents the amount of dissolved oxygen consumed by bacteria during the decomposition of organic matter in water. While BOD contributes to the Total COD, the median results after RO treatment indicate a concentration of zero, suggesting a significant reduction in organic matter. Even for Soluble COD, the medians do not exceed the standard. However, the sequential treatment process demonstrates excellent results in organic matter reduction, as evidenced by the marked decrease in both Total COD and Soluble COD after treatment.

Accordingly, all inlet wastewater samples collected did not exhibit a normal distribution, indicating that the characteristics in terms of turbidity, pH, total and soluble COD are not consistent. Conversely, with the exception of pH and soluble COD of samples from point II, and pH from samples from point III, all the other parameters from points II and III exhibit consistent characteristics.

Given that the WWTP receives actual wastewater with varying characteristics and considering the treatment configuration, it is possible to conclude that the MBR and RO sequence demonstrates good resilience in handling these fluctuations. Additionally, the company managing the WWTP provided consultation, and there were no adverse impacts on the development of the air conditioning system due to water reuse.

Indeed, the present study did not assess certain parameters such as fecal coliform, biocide level, total iron, chlorine residual, and others. However, it is important to acknowledge the promising results obtained for the parameters that were analysed. This highlights the potential for water reuse in technology parks, particularly for air conditioning systems, especially in locations like the urban fringe where the studied WWTP operates. This WWTP utilizes a combination of MBR and OR as a decentralized system, showcasing its effectiveness and suitability for such contexts.

Water reuse presents itself as viable alternative for promoting the sustainable utilization of natural resources, aligning with the principles advocated for in the fourth generation of technology parks. In addition to its application in air conditioning systems, it offers the opportunity to maximize resource efficiency. However, it's essential to consider the energy consumption associated with processes like RO. According to Kumar Singh et al. (2021), operating with a crossflow rate of 1 L/min, the specific energy consumption is about of 0.50 ± 0.03 kWh/m^3. This underscores the importance of balancing the benefits of water reuse with the energy requirements of treatment processes to ensure overall sustainability.

4 Conclusion

In conclusion, this study evaluated the effluent produced by integrating a Membrane Bioreactor (MBR) and Reverse Osmose (RO) in a practical Wastewater Treatment Plant (WWTP) designed for utilization in air conditioning systems applicable to technology parks. The results indicate that a high-quality effluent suitable for the intended purpose can be obtained, although energy consumption considerations are paramount. Particularly, the RO process necessitates a notable amount of energy, akin to the air conditioning system itself. Therefore, exploring sustainable energy sources within technology parks could be a viable approach to sustain the process efficiently.

This holistic approach can significantly contribute to enhancing the sustainability and efficiency of decentralized wastewater treatment systems, especially within the context of technology parks and the quintuple helix model. The opportunity to promote Brazilian standards for water reuse is particularly significant, especially in the advancement of fourth-generation technology parks. By adopting and advocating standards tailored to Brazil's specific needs and environmental conditions, such as those related to water reuse, these technology parks can play a pivotal role in fostering sustainable development and resource management practices customized to the Brazilian context.

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