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# Optimal Conditions for Simultaneous Textile Effluent Treatment and Biomass Production by Combined Ozonation-Microalgae Process

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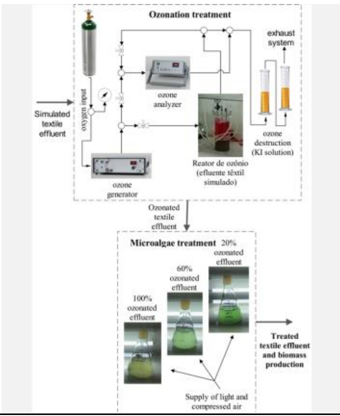


Ozonation process has shown good results in removing dyes, increasing the biodegradability of effluents from textile industry. Nevertheless, it can be an unfeasible treatment from an economic point of view. Thus, it becomes more attractive when combined with economically-feasible processes, such as biological processes. The combined ozonation-microalgae process can be a sustainable path for both, the remediation of colored effluents and the biomass production. The integration of ozonation and microalgae processes for remediating textile effluents while simultaneously generating biomass remains an unexplored avenue of research. In this paper, the optimal values for key operational variables of the above-mentioned combined process were determined. Through this investigation, the operating conditions to maximize the production of microalgal biomass and simultaneously guarantee the effective remediation of the effluent were found.

## Introduction

Textile industry effluents are highly polluting. Specifically, the dyes can cause severe damage to water bodies, leading to death of many aquatic organisms [1]. Among several technologies, ozonation process has shown good results in removing dyes [2]. Nevertheless, ozonation can be unfeasible from an economic point of view. Ozonation becomes more attractive when combined with biological processes. Among the biological processes, the use of microalgae has aroused great interest. In addition to the effluent remediation itself, microalgae reproduce quickly, increasing their biomass, and can be used as precursors in the production of oils and biomass for animal nutrition [3]. The combined ozonation-microalgae process can be a sustainable path for both, the remediation of colored effluents and the biomass production. However, the integration of ozonation and microalgae processes for remediating textile industry effluents while simultaneously generating biomass remains an unexplored avenue of research. In this paper, the optimal values for key operational variables of this combined process were determined, identifying the operating conditions that maximize the production of microalgal biomass and simultaneously guarantee the effective remediation of the effluent.

## Material and Methods

The simulated textile effluent was based on the study of Yaseen and Scholz [4]. First, the simulated textile effluent was ozonated in a 1 L reactor using an ozone dose of 15.50 $mgO_3.min^{-1}.L^{-1}$. After that, the ozonated effluent was used to compose a mixed culture medium (comprising ozonated effluent and ASM-1 medium) for microalgae cultivation. All experiments were conducted in Erlenmeyer containing 800 mL of culture medium. The initial concentration of *Chlorella sorokiniana* was approximately 0.10 $g.L^{-1}$. The microalgae cultures were maintained for a period of 14 days, without adding more nutrients after inoculation.

A face-centered central composite design (CCD) was made for evaluating the performance of the combined ozonation-microalgae process. Three independent variables were considered: ozone treatment time (OT), with levels of 10, 15 and 20 min; microalgae aeration (MA), with levels of 1, 2 and 3 $L.min^{-1}$; and proportion of ozonated effluent (PE), with levels of 20, 60 and 100% v/v. The experimental design generated 17 experiments. The dependent variables chosen for quantify the effluent remediation were: color, phosphorus (P), ammoniacal nitrogen ($N\text{-}NH_3$) and Chemical Oxygen Demand (COD), in terms of removal (%). Meanwhile, the biomass production was assessed by using the average biomass productivity ($g.L^{-1}.d^{-1}$).

Response surface methodology (RSM) was applied to identified the relationship between factors and dependent variables setting a threshold for significance of $p < 0.05$. The capability of the obtained models was tested using the model predicted vs. experiential values plot, the normal probability of the residuals plot, as well as the F-test, which allowed comparing the model's prediction variance with the experimental variance. The fitting of the response surfaces and the regression analysis were performed using the software *STATISCA, version 10.0.*

## Results and Discussion

The combined ozonation-microalgae process was not effective in COD removal, since an increase on this parameter was observed. This behavior was attributed to the accumulation of organic compounds generated through the metabolic activities of microalgae. Similar results were obtained in [5].

Although the ozonation treatment demonstrated inefficiency in removing $N\text{-}NH_3$, the overall combined process proved highly effective in reducing $N\text{-}NH_3$, achieving removal rates above 96% for all experiments. The resultant ammonia concentrations were below 1.30 $mg.L^{-1}$, demonstrating compliance with the regulatory standards of Rio de Janeiro (NT-202.R-10).

P removal during the ozonation treatment was notably low. These findings align with results reported in [6]. In contrast, the microalgae treatment exhibited greater effectiveness in P removal. Consequently, five experiments achieve P removal higher than 90% in the combined process, meeting the established criterion by the NT-202.R-10 technical standard.

The integrated ozonation-microalgae process successfully eliminated color from the effluent, reducing it to levels where it became practically imperceptible. Ozonation had an important role in facilitating the degradation of color during the treatment.

Biomass production was observed in all experiments, indicating that the different proportions of ozonized textile effluent and ASM1 medium were favorable to the growth *Chorella sorokiniana*.

The optimal operating conditions were found to be OT = 19.30 min, MA = 3 $L.min^{-1}$, and PE = 100%. These conditions resulted in color removal of 94.33%, P removal of 94%, and productivity of 3.18 x $10^{-2}$ $g.L^{-1}.d^{-1}$. The mathematical models obtained for color removal (CR) and phosphorus removal (PR), expressed in percentage, as well as, for biomass productivity (BP), expressed in $g.L^{-1}.d^{-1}$, were as follows:

$$CR = 40{,}13854 + 4{,}05521*TO - 0{,}06723*TO^2 + 0{,}06334*CE - 0{,}00196*TO*CE - 0{,}00524*AM*CE$$

$$PR = 49{,}57737 + 5{,}88553*TO - 0{,}25972*TO^2 - 19{,}14030*AM + 5{,}37208*AM^2 + 0{,}03333*CE + 0{,}01726*TO*CE$$

$$BP = 0{,}00110 + 0{,}00122*TO - 0{,}00112*AM^2 - 0{,}00007*CE - 0{,}00005*TO*AM + 0{,}00009*AM*CE$$

## Conclusions

The combined ozone-microalgae process was effective in the removal of ammoniacal nitrogen and phosphorus. These contaminants were primarily removed by the microalgae treatment; meanwhile, the ozonation treatment was mainly responsible for removing color from the effluent. The combined process also showed effectiveness in microalgal biomass production, indicating that ozonized textile effluent can be used as a cultivation medium for the growth of *Chlorella sorokiniana*. Nevertheless, it proved insufficient in reducing COD, being unable to make the effluent suitable for discharge. However, it is possible to assume that the majority of this organic matter is biodegradable, allowing COD to be easily removed in oxidation ponds. The fitted regression model was essential to identify the optimal values of the studied variables: ozone treatment time at 19.30 min, microalgae aeration at 3 $L.min^{-1}$, and proportion of ozonated effluent at 100%. Under these conditions, remarkable results were achieved, including a 94.33% removal of color, a 94% phosphorus removal rate, and a productivity of 3.18 x $10^{-2}$ $g.L^{-1}.d^{-1}$.

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