Treatment of an effluent from a poultry slaughterhouse through a coupled ozone and photo-Fenton process using a biocatalyst

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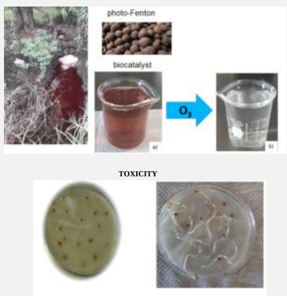

Poultry slaughterhouse wastewater (PSW) has been associated with negative environmental impacts due to the foul odor and reddish color of the effluent. Hence, this study proposes an alternative for treating this type of effluent by employing an iron biocatalyst for use in the Fenton and photo-Fenton processes, utilizing two types of light sources (UV and Vis). The biocatalyst was characterized using X-ray diffraction (XRD), and at the end of each treatment, total organic carbon (TOC) and phytotoxicity were determined. The results indicate that ozone only removes 9% of TOC and exhibits low toxicity towards Lactuca Sativa seeds. Conversely, UV and Vis photo-Fenton processes achieve TOC reductions of 56% and 51%, respectively, yet only 62 and 61% of germination index (GI), indicating moderate phytotoxicity.

Introduction

In poultry slaughterhouses, complex wastewater is produced, containing high concentrations of fats, suspended solids, and organic matter [1]. Therefore, the properties of poultry slaughterhouse wastewater (PSW) have been associated with negative environmental impacts on receiving water bodies, such as sludge deposits and decreased oxygen levels. All the factors mentioned above contribute to a disagreeable visual and olfactory experience, primarily due to the odors and reddish coloration that characterize the effluent where this type of wastewater is discharged.

The aim of this study was the treatment of the contaminated effluent using ozonation as a pre-treatment to remove color and odor, followed by Fenton and photo-Fenton processes employing xanthated pepper with iron as a biocatalyst, hydrogen peroxide, and UV and visible light. Finally, toxicity was evaluated at the beginning and end of each treatment.

The efficiency of the treatment system was determined both before and after, with regard to Total Organic Carbon (TOC) [2].

Material and Methods

The modification of pepper residues was carried out through the Xanthation reaction according to Palma-Anaya 2017 [3], with the addition of iron particles supported on said biomaterial, which was used as a biocatalyst in the photo-Fenton process.

The ozonation system, as reported by Amado-Piña et al. 2022 [2] and the photo-Fenton process, as detailed by Olea-Mejia et al. 2023 [4], were employed. This entailed utilizing a total volume of 500 mL, a UV lamp emitting at 254 nm, and a system comprising three visible light lamps, hydrogen peroxide was used at a stoichiometric concentration, along with 500 mg of xanthated pepper biomaterial with iron (cpX-Fe). The samples underwent pre-treatment with ozone for 60 minutes, followed by treatment with adsorption using xanthated Jamaican pepper with Fe (cpX-Fe), Fenton (cpX-Fe+ H_2O_2), and photo-Fenton (cpX-Fe+ H_2O_2+ UV/Vis). The total treatment duration for the samples was 180 minutes, which included the initial 60 minutes of ozone treatment. Upon completion of the treatment process, Total Organic Carbon (TOC) levels were determined using a Shimadzu equipment model TOC-L, and toxicity tests with Lactuca sativa were conducted according to Amado-Piña [2].

Results and Discussion

The initial pH of the effluent was 8.1, and the initial TOC in the solution was 196 mg/L. Ozone was employed as a pre-treatment and resulted in the removal of only 9.4% of the TOC (see figure 1). Meanwhile, the results obtained with adsorption using cpX-Fe, photo-Fenton with UV, photo-Fenton with visible light, and Fenton were as follows: 29, 56, 51, and 35% removal of TOC, respectively. Notably, the photo-Fenton process utilizing UV and visible light demonstrated greater efficiency (>50%) attributed to the generation of more hydroxyl radicals (OH•) compared to the Fenton process and adsorption.

The results of the toxicity test conducted at the end of each treatment are presented in table 1. The percentage of Germination Index relates to the quantity of seeds germinated within 5 days under dark conditions at 22 ± 2 ℃ and the length of the roots of those germinated *Lactuca sativa* seeds, reflecting the degree of toxicity or phytotoxicity.

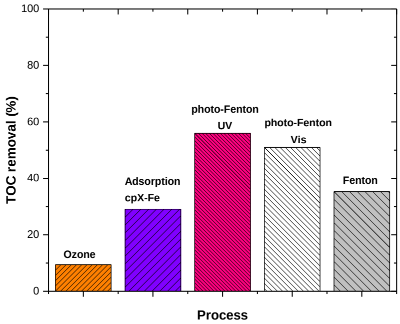

Figure 1. Efecto del tipo de proceso sobre la remoción de COT en el efluente proveniente ARMA.

Values close to zero indicate high phytotoxicity (H), values near 50% indicate moderate toxicity (M), and values close to or equal to 100% indicate low or no toxicity (L). In Table 1, it can be observed that only the negative control attains a GI of 100%, followed by ozone with 83%; however, values with moderate toxicity > 60% are evident in adsorption with xanthated pepper with iron and UV and Vis photo-Fenton, while Fenton exhibits 15%, equal to the initial sample, and finally, the positive control shows 8%. In other words, although the samples still contain more than 50% organic load, the treatments do not completely remove toxicity for the same reasons. Conversely, with ozone, which only removes 9% of TOC but is capable of largely stimulating seed and root germination, resulting in a higher GI percentage. Photo-Fenton is essentially the Fenton process with the addition of a radiation source in the form of light, which can be UV or visible. This photon source not only aids in degrading the organic load but also, if sufficiently energetic, contributes to the dissociation of hydrogen peroxide and the chemical photoreduction of Fe^{3+} ions to Fe^{2+}, thereby regenerating the hydrogen peroxide dissociation catalyst and providing an additional pathway for producing hydroxyl and hydroperoxyl radicals, resulting in an increase in the GI percentage. With this, it can be explained that in the Fenton process, where the photoreduction of Fe^{3+} ions does not occur, they may be contributing to the observed high phytotoxicity (H).

Table 1. Percentage of Germination Index (GI) of *Lactuca sativa* seeds at the end of each treatment.[a]

Process	GI (%)	Phytotoxicity
Initial	15	H
Ozone	83	L
Adsorption cpX-Fe	61	M
Fenton	15	H
photo-Fenton Vis	61	M
photo-Fenton UV	62	M
Positive control	8	H
Negative control	100	L

[a] Negative control (destiled water), positive control (Zn (II) $ZnSO_4.7H_2O$, 25 mg/L of Zn^{2+}).

Conclusions

Based on the results, it can be concluded that ozone application can be used as a pre-treatment for color and odor removal, as well as a disinfectant for treating effluent from PSW. Ozone demonstrates the capability to partially remove organic load and degrade compounds commonly found in biological fluids present in wastewater, thereby reducing phytotoxicity. On the other hand, photo-Fenton processes utilizing UV and visible light remove more than 50% of TOC when employing xanthated pepper with iron (cpX-Fe) as a biocatalisyt; however, they only manage to decrease the phytotoxicity from initially high to moderate. Finally, in Fenton process where the photoreduction of Fe^{3+} ions does not occur, they may be contributing to higher phytotoxicity (H) compared to photo-Fenton processes.

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