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Winemaking Wastewater Treatment: Hydrodynamic Cavitation and Coagulation-Flocculation

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Abstract Winery wastewater poses significant environmental risks due to high concentrations of organic and inorganic compounds. This study examines the treatment of wastewater from the "Torre di Morro" winery using hydrodynamic cavitation and coagulation-flocculation processes. Cavitation at 3 bar achieved a 33% pollutant degradation, while Fenton's reagents increased this to 60%. The combination of cavitation and Fenton's reagents was most effective, resulting in a 74% reduction. Coagulant dosages of 5 mg/L, 12.5 mg/L, and 100 mg/L led to COD reductions of 50%, 58%, and 60%, respectively. These findings demonstrate that combined methods significantly enhance treatment efficiency, offering a promising approach for winery wastewater purification. Implementing these methods can substantially reduce the environmental impact of winery wastewater, contributing to more sustainable winemaking practices.

Keywords: Hydrodynamic cavitation, Fenton process Coagulation-Flocculation, winery wastewater

1. Introduction

Winery wastewater is characterized by high concentrations of organic and inorganic compounds, low pH, and fluctuating salinity and nutrient levels, posing significant environmental risks.[1] For instance, wineries typically produce 3 to 5 cubic meters of effluent per ton of crushed grapes. In the 2018-2019 season, the South African wine industry alone generated approximately 3.6 to 6 million cubic meters of wastewater. Similarly, the European wine industry, a major global player, produces substantial volumes of wastewater, with Italy, France, and Spain generating millions of cubic meters annually.[2]

The pollutants in winery wastewater, including ethanol, sugars, phenolic compounds, and organic acids, necessitate effective treatment methods to mitigate environmental impacts. Common pollutants such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Solids (TS), and Suspended Solids (SS) highlight the variability and complexity of winery wastewater. [3,4]

This paper explores the treatment of wastewater generated from winemaking activities, focusing on the use of hydrodynamic cavitation and coagulation-flocculation processes. The aim is to optimize these methods for effective purification and environmental sustainability. [5]

2. Materials and Methods:

a- Characterization of Winery Wastewater:

Wastewater from the "Torre di Morro" winery was analyzed at the University of L'Aquila. Tests measured contaminants, TOC, COD, and TSS. Spectrophotometric methods detected ammonium and nitrate chloride. Results are summarized in the table.

Table 1. Characteristics of effluent

Parameter	Range	Unit
pH	7	-
Chemical oxygen	1200	mg/L
Total Organic carbon	42.40	mg/L
Biochemical oxygen	4280	mg/L
Phenols	1.00	mg/L
Ammonium	0.15	mg/L
Chloride	12.90	mg/L
Nitrate	1.29	mg/L
Sulfates	36.70	mg/L

The experiment assessed various chemical coagulation and flocculation methods for treating winery wastewater, utilizing calcium hydroxide, aluminum sulfate, ferric chloride, and ferrous sulfate as coagulants. pH adjustments were performed using sulfuric acid and sodium hydroxide, while aluminum chloride was added to achieve specific aluminum concentrations. Five different tests were conducted to evaluate the treatment effectiveness. Tests 1 and 2 involved clarification-flocculation with

sedimentation times of one hour and 24 hours, respectively. Test 3 implemented filtration followed by hydrodynamic cavitation to enhance wastewater treatment. Tests 4 and 5 focused on oxidative treatment through the addition of 1.67 mL and 5 mL of hydrogen peroxide without prior clarification-flocculation..

3. Results

The TOC and COD analyzers were employed to measure total organic carbon (TOC) and chemical oxygen demand (COD) in the winery wastewater. The chemicals used for these analyses were test cuvettes (LCK114 for TOC and LCK381 for COD). Total solids (TSS) were determined by drying the effluent sample in an oven at 104°C (UF160) for 24 hours.

The results obtained are figures1,2, which details the characteristics of the effluent. The most likely pollutants identified in the effluent include chlorinated compounds, nitrogen, and sulfates. The study revealed that cavitation alone, at a pressure of 3 bar, achieved a 33% degradation of pollutants, while Fenton's reagents increased the degradation rate to 60%. The combination of cavitation and Fenton's reagents was the most effective, resulting in a 74% reduction in pollutants. Additionally, different coagulant dosages of 5 mg/L, 12.5 mg/L, and 100 mg/L led to COD reductions of 50%, 58%, and 60%, respectively. These findings highlight that while each method is beneficial on its own [8], their combined application significantly enhances the overall efficiency of the treatment process.[6,7]

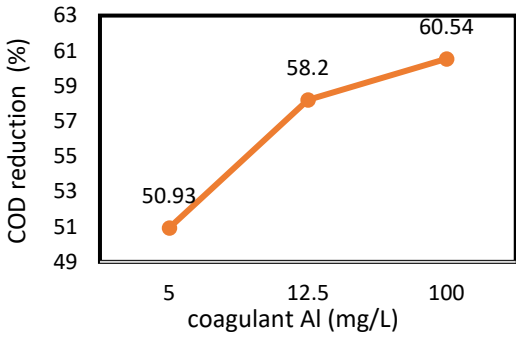

Figure 1. COD reduction obtained for different coagulant dosage

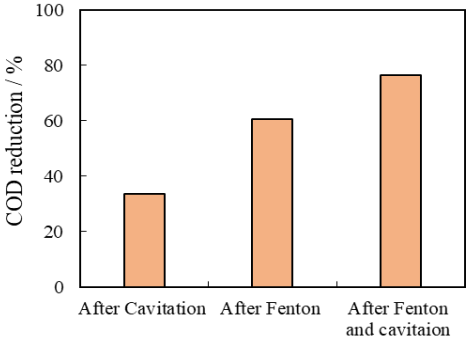

Figure 2. Extent of COD and Phenols reduction obtained for different approaches

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