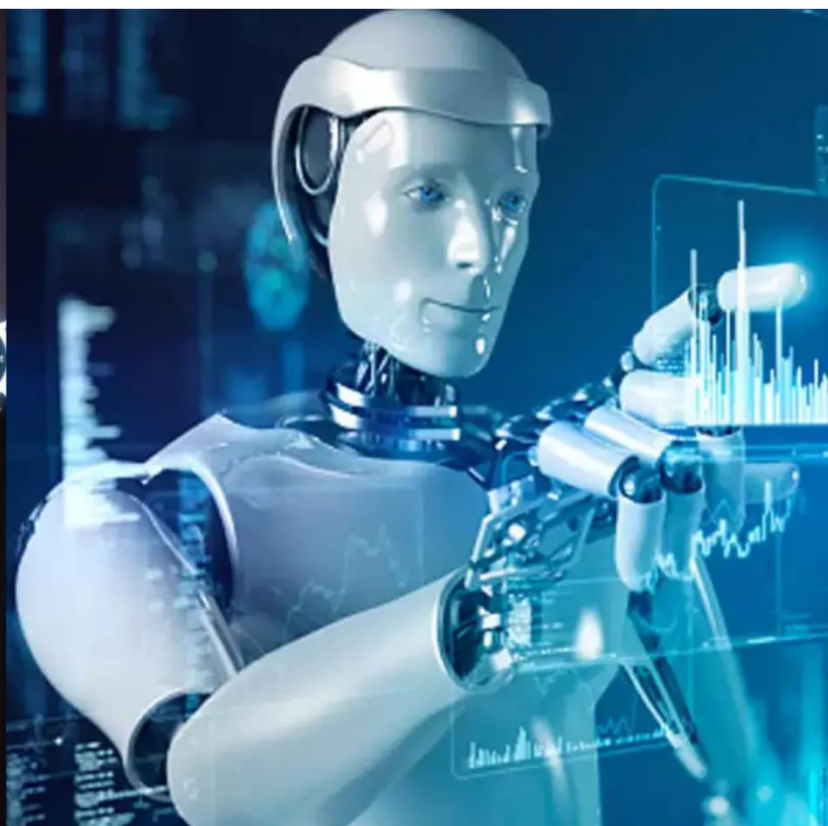




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# **Treatment of Industrial Wastewater using the Fenton Process**

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**ABSTRACT:** This study evaluates the efficacy of the homogeneous Fenton oxidation process ( $\text{Fe}^{2+}/\text{H}_2\text{O}_2$ ) for treating a single batch (500 mL) of chemical industry wastewater. Under optimized conditions (pH 3.0, 10 mg/L  $\text{Fe}^{2+}$ , 100 mg/L  $\text{H}_2\text{O}_2$ ), the treatment achieved substantial reductions in organic load, with BOD decreasing from 240 to 28 mg/L and COD from 510 to 80 mg/L. pH was neutralized after treatment to 7.2, and chloride and temperature values remained within BIS discharge limits. Nitrate and fluoride were reduced but remained above BIS potable limits, indicating the need for post-treatment. The results demonstrate the Fenton process as an effective primary or pre-treatment step for complex industrial effluents and support its application for non-potable reuse scenarios.

**KEYWORDS:** Fenton process; advanced oxidation; industrial wastewater; hydroxyl radicals; BIS standards

## **I. INTRODUCTION**

Industrial wastewater from chemical manufacturing often contains a mixture of refractory organics, toxic components, and elevated ionic species that limit the effectiveness of conventional biological treatment. Advanced Oxidation Processes (AOPs) generate strong oxidants such as hydroxyl radicals ( $\cdot\text{OH}$ ) that can oxidize a broad spectrum of pollutants. The Fenton reaction, which involves the catalytic decomposition of hydrogen peroxide by ferrous iron, is particularly attractive due to its operational simplicity, low capital requirements, and high oxidation potential under mildly acidic conditions. This work applies the Fenton process to a representative chemical industry effluent and quantifies performance in terms of key regulatory and operational parameters.

## **II. OBJECTIVES**

The study focuses on three primary objectives:

1. Evaluate the efficiency of homogeneous Fenton oxidation in reducing BOD, COD, and other priority pollutants in chemical-industry wastewater.
2. Compare treated effluent quality with BIS standards to determine compliance and reuse potential.
3. Assess practical implementation considerations and identify additional polishing steps required for potable reuse.

## **III. STUDY AREA AND SAMPLE**

A composite influent sample was collected from a chemical industry outlet within an industrial estate. Exact location details are withheld for confidentiality. A 500 mL aliquot was used for batch-scale laboratory experiments. Samples were stored at 4 °C and analyzed promptly following standard methods.

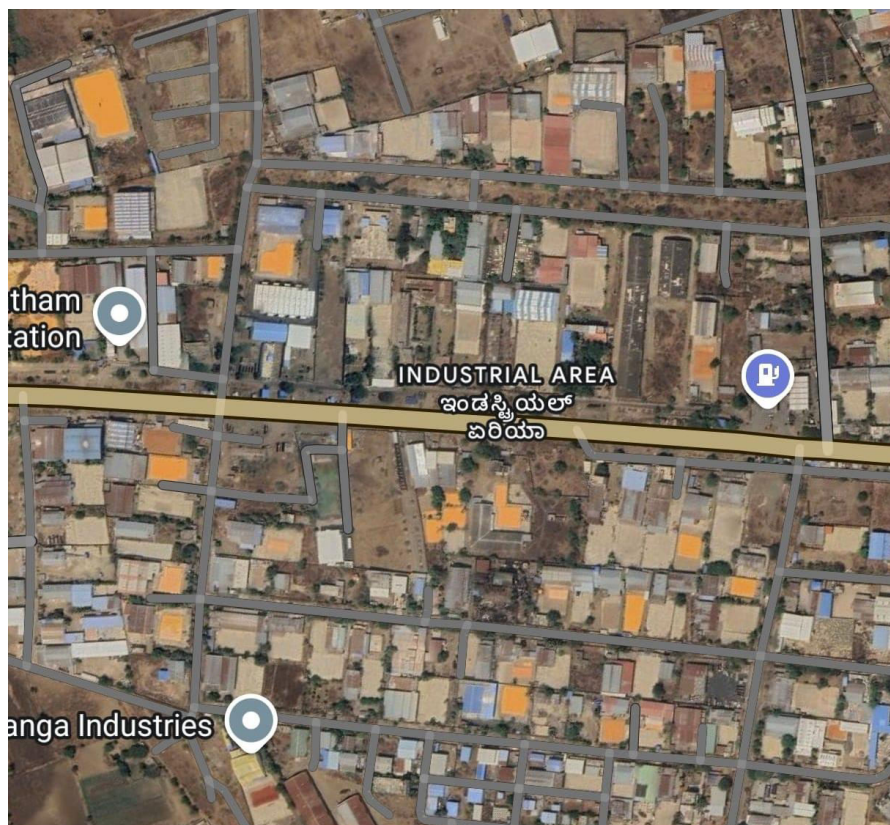


Fig 3.1 Location of Industrial Area (Sampling Site)

The wastewater sample used in this study was collected from the chemical industrial area shown in the above map. This region hosts multiple small- and medium-scale chemical manufacturing units, producing dyes, solvents, and intermediates, which are known to generate high-strength effluents. The site was chosen due to its representative nature of chemical industry discharges and its relevance to real-world wastewater treatment challenges. The composite sample was collected at the outlet of the effluent discharge channel within this industrial estate and transported to the laboratory under controlled conditions for further analysis.

#### IV. METHODOLOGY

##### 4.1 Materials and Reagents

Reagents: 30% hydrogen peroxide ( $\text{H}_2\text{O}_2$ ), ferrous sulfate heptahydrate ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ), 1 N  $\text{H}_2\text{SO}_4$  and 1 N  $\text{NaOH}$ . Distilled water was used for dilutions.

##### 4.2 Experimental Setup

Batch experiments were performed in a 1 L glass beaker on a magnetic stirrer at 200 rpm. pH was measured using a calibrated digital pH meter. Filtration was performed using a vacuum assembly and filter paper.

##### 4.3 Experimental Procedure (Fenton Process)

Sample volume: 500 mL. Initial measured pH: 5.8.

Step 1: pH adjustment to 3.0 using 1 N  $\text{H}_2\text{SO}_4$  (approx. 1.75 mL added dropwise) while stirring at 200 rpm.

Step 2: Addition of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  to achieve 10 mg/L  $\text{Fe}^{2+}$  (50 mg dissolved in 25 mL distilled water), added slowly over 3 minutes.

Step 3: Addition of  $\text{H}_2\text{O}_2$  (30% stock) to achieve 100 mg/L (0.165 mL stock diluted  $10\times$  to 1.65 mL working solution) added dropwise over 2 minutes. Mild effervescence and a small temperature rise observed.

Step 4: Reaction maintained for 60 minutes at  $30 \pm 2$  °C under continuous stirring; color and odor changes monitored.  
Step 5: Reaction quenching and neutralization with 1 N NaOH to pH 7.2;  $\text{Fe}(\text{OH})_3$  precipitated as brown sludge.  
Step 6: Vacuum filtration using Whatman No. 42; filtrate collected and sludge dried at 105 °C for dry weight determination.



Fig 4.3.1: Industrial wastewater before treatment

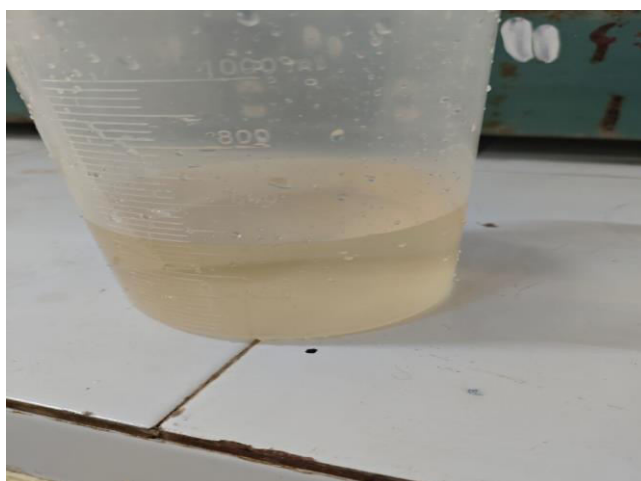


Fig 4.3.2: Industrial wastewater after treatment

#### 4.4 Analytical Methods

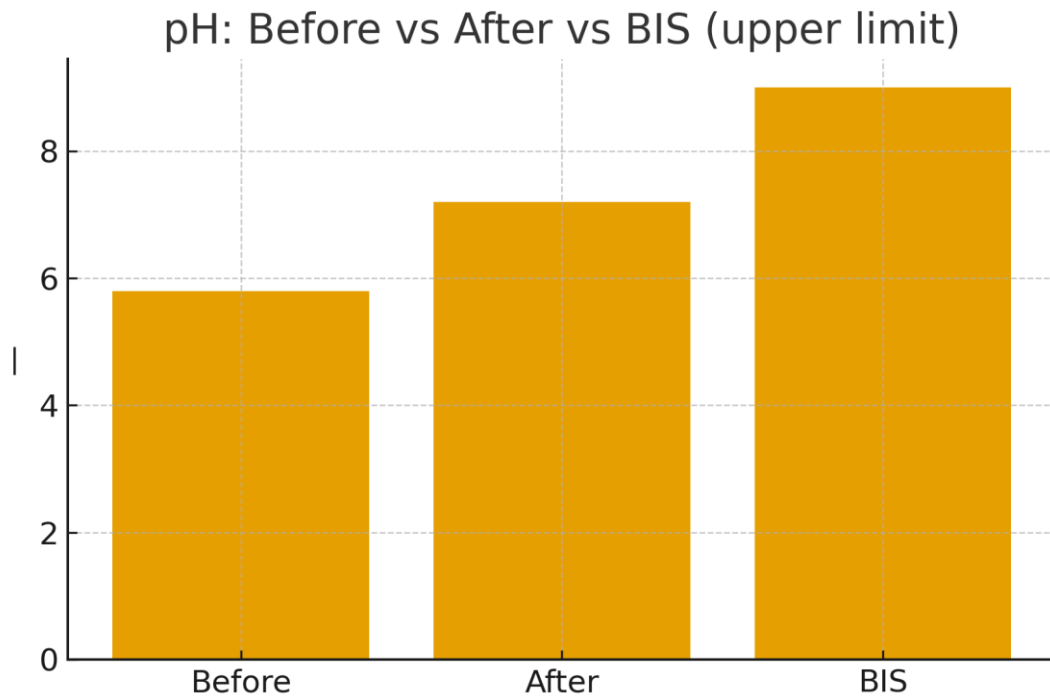
pH measured with digital pH meter. BOD (5-day), COD (closed reflux), chloride, nitrate, and fluoride were determined using standard APHA methods.

### V. RESULTS AND DISCUSSION

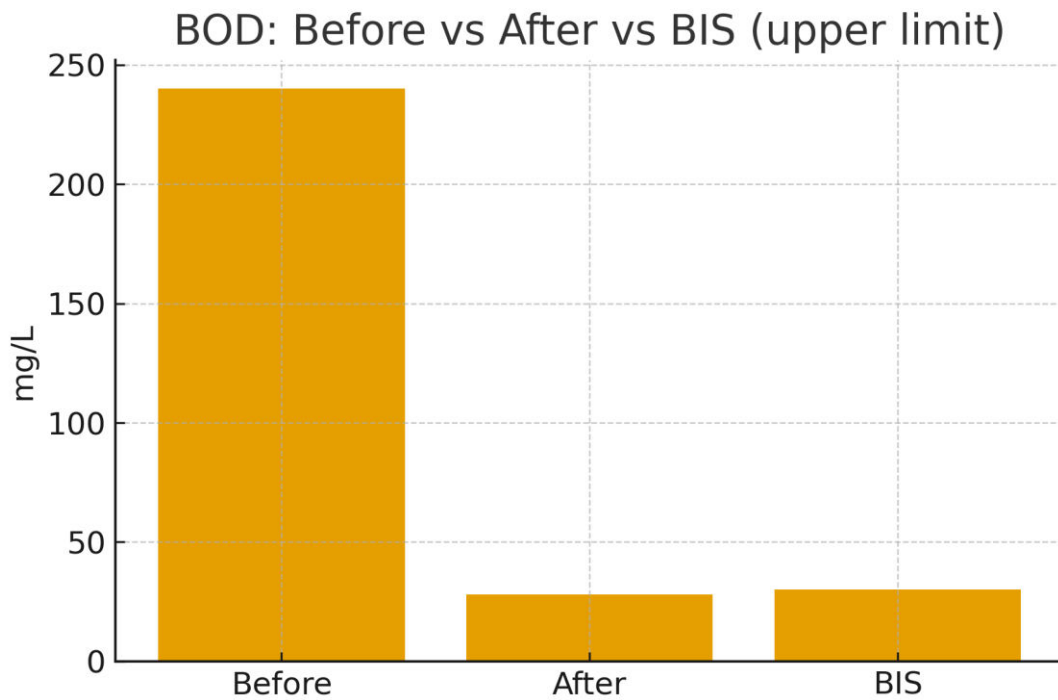
Table 1 below summarizes the measured parameters before and after Fenton treatment, along with BIS limits for comparison.

Table 1: Wastewater quality parameters before and after Fenton treatment compared with BIS limits

Parameter	Unit	Before Treatment	After Treatment	BIS Standard Limit
pH	—	5.8	7.2	6.5–9.0
BOD	mg/L	240	28	$\leq 30$
COD	mg/L	510	80	$\leq 250$
Chloride	mg/L	370	310	250–1000
Nitrate	mg/L	42.5	31.5	$\leq 10$
Fluoride	mg/L	3.7	2.1	$\leq 1.5$
Temperature	°C	33	32	$< 40$



**Figure: pH comparison (Before, After, BIS).**



**Figure: BOD comparison (Before, After, BIS).**

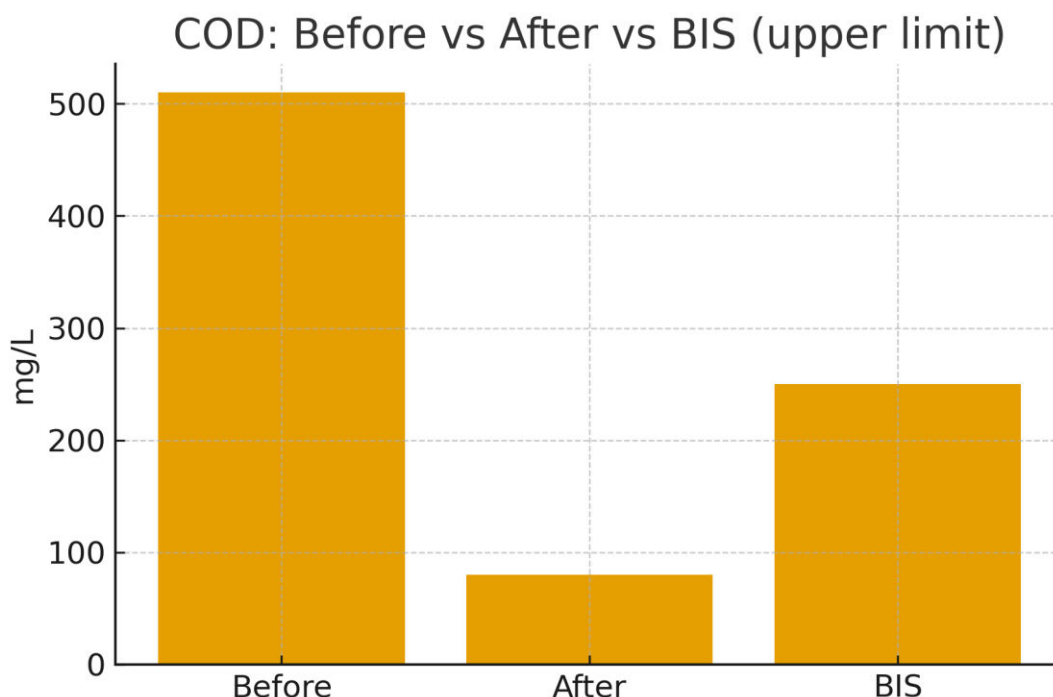


Figure: COD comparison (Before, After, BIS).

### 5.1 Organic Load Reduction (BOD & COD)

The Fenton process achieved marked reductions in both BOD and COD. BOD dropped from 240 mg/L to 28 mg/L ( $\approx 88\%$  removal), while COD decreased from 510 mg/L to 80 mg/L ( $\approx 84\%$  removal). These reductions confirm effective attack on both biodegradable and refractory organics via hydroxyl radical oxidation. The post-treatment BOD/COD ratio suggests improved biodegradability, making the effluent amenable to secondary biological polishing if needed.

### 5.2 pH and Process Control

The initial pH of 5.8 was adjusted to 3.0 to optimize hydroxyl radical production. After oxidation and neutralization, final pH was 7.2, within BIS discharge limits. Maintaining pH control is critical to prevent iron precipitation during the oxidative stage and to enable efficient radical generation.

### 5.3 Inorganic Species: Chloride, Nitrate, Fluoride

Chloride exhibited a modest decrease (370  $\rightarrow$  310 mg/L) likely due to co-precipitation or adsorption onto formed iron hydroxides; it remains within BIS discharge boundaries. Nitrate and fluoride showed partial reductions (42.5  $\rightarrow$  31.5 mg/L and 3.7  $\rightarrow$  2.1 mg/L respectively) but stayed above potable limits, indicating that the Fenton process alone is insufficient for their complete removal. Targeted polishing such as ion exchange, activated alumina adsorption, or reverse osmosis is recommended for potable-grade recovery.

### 5.4 Temperature and Operational Observations

The reaction proceeded under ambient temperature ( $\approx 30\text{--}33\text{ }^{\circ}\text{C}$ ) with only minor exotherm during  $\text{H}_2\text{O}_2$  addition. No operational hazards were observed at the laboratory scale. Sludge generated as  $\text{Fe}(\text{OH})_3$  was easily separated via vacuum filtration and dried for mass quantification ( $\sim 0.215\text{ g}$  dry weight from 500 mL).

### 5.5 Reuse Potential and Limitations

Post-treatment, the effluent meets BIS discharge limits for pH, BOD, COD, chloride, and temperature, making it suitable for non-potable reuse (toilet flushing, industrial cooling, and irrigation with caution). However, elevated nitrate

and fluoride preclude direct potable reuse without further polishing. Economic and operational considerations suggest the Fenton process is best deployed as a pre-treatment or primary oxidation stage in an integrated treatment train.

## VI. CONCLUSION

The homogeneous Fenton process effectively reduced organic pollutants in chemical industry wastewater under lab-scale conditions, achieving regulatory compliance for several key parameters. To achieve potable standards, additional polishing steps targeting nitrate and fluoride are necessary. The method's operational simplicity and rapid kinetics make it a viable option for industrial wastewater pre-treatment and water reuse strategies.

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