

# Treatment of Industrial Wastewater Using the Fenton Process

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**Abstract:** This manuscript reports an extended laboratory-scale evaluation of homogeneous Fenton oxidation ( $\text{Fe}^{2+}/\text{H}_2\text{O}_2$ ) applied to a representative composite sample of chemical industry wastewater from an industrial estate. The work was carried out under optimized laboratory conditions ( $\text{pH} \approx 3.0$ ;  $\text{Fe}^{2+} = 10 \text{ mg/L}$ ;  $\text{H}_2\text{O}_2 = 100 \text{ mg/L}$ ) in batch mode. The Fenton process delivered substantial reductions in organic load (BOD:  $240 \rightarrow 28 \text{ mg/L}$ ; COD:  $510 \rightarrow 80 \text{ mg/L}$ ), turbidity, and certain inorganic constituents, while neutralization and filtration removed iron-rich precipitates. Photographs of untreated and treated samples and the sampling location are included, together with comparative graphs for key parameters.

**Keywords:** Fenton process; advanced oxidation; industrial wastewater treatment; hydroxyl radicals; BIS standards; sludge management.

## I. INTRODUCTION

Industrial wastewater generated by chemical and allied industries often contains complex mixtures of organic contaminants, colored dyes, solvents, and inorganic salts. In many parts of India, including industrial clusters in Karnataka, such effluents pose risks to surface water quality, groundwater recharge, and downstream users when discharged without adequate treatment. Conventional biological systems can be ineffective for refractory organics or high-strength wastewaters, and physicochemical methods can be costly or generate concentrated wastes. Advanced Oxidation Processes (AOPs) — particularly the classical Fenton reaction — provide a promising alternative for rapid oxidation of recalcitrant organics using hydrogen peroxide and ferrous iron as a catalyst.

The Fenton reaction proceeds via generation of hydroxyl radicals ( $\bullet\text{OH}$ ), highly reactive oxidants that non-selectively attack organic molecules.  $\text{Fe}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{3+} + \text{OH}^- + \bullet\text{OH}$ .  $\text{Fe}^{3+}$  can be regenerated under certain conditions or precipitated as ferric hydroxide after neutralization, which facilitates separation. Key operational parameters include pH (optimal  $\approx 2.5\text{--}3.5$ ),  $\text{Fe}^{2+}$  dose,  $\text{H}_2\text{O}_2$  dose, reaction time, and mixing intensity.

## II. OBJECTIVES

The specific objectives of this study were:

- To evaluate the treatment efficiency of the homogeneous Fenton process on a chemical industry wastewater sample focusing on BOD, COD and turbidity.
- To quantify removal of selected inorganic constituents (chloride, nitrate, fluoride) and to assess compliance with BIS discharge standards.
- To document operational observations (sludge formation, temperature change, safety notes) and discuss practical considerations for plant-scale implementation.
- To provide a clear, publication-ready manuscript with photographic evidence and methodological detail suitable for journal submission.

**III. STUDY AREA AND SAMPLE**

Composite influent samples were collected from the outlet of a chemical manufacturing unit located within a local industrial estate. Exact site coordinates are withheld for confidentiality; the sampling location is a mixed-chemical processing facility in the Kalaburagi region. The grab-composite sample (total 2 L) was homogenized and a 500 mL aliquot used for each batch experiment. Samples were stored at 4 °C and analyzed within 24 hours following standard APHA procedures.

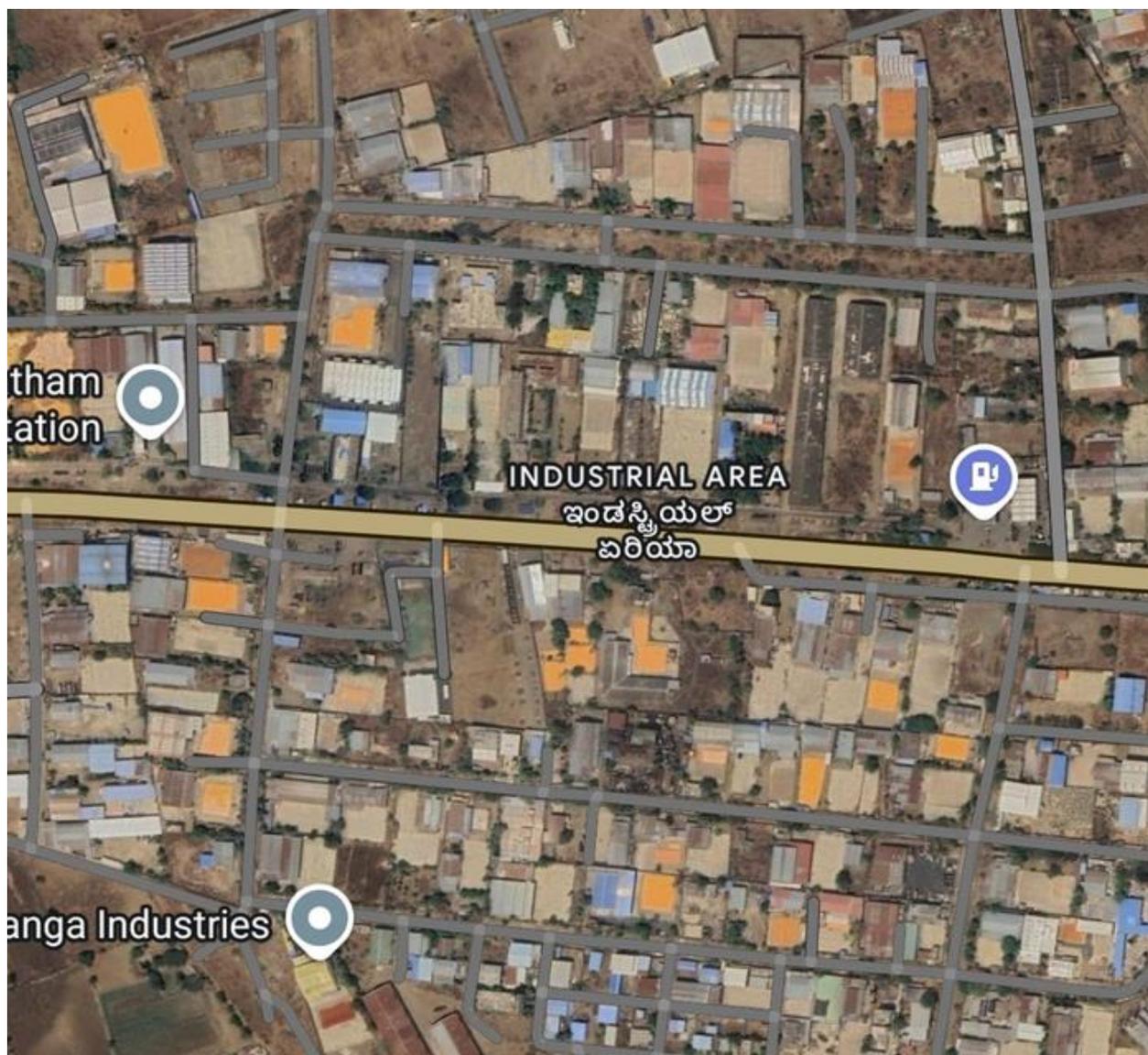


Figure 1: Sampling location (industrial area).

**IV. METHODOLOGY****4.1 Materials and Reagents**

Analytical-grade reagents were used. Key reagents included 30% H<sub>2</sub>O<sub>2</sub> (as oxidant), ferrous sulfate heptahydrate (FeSO<sub>4</sub>·7H<sub>2</sub>O) as the Fe<sup>2+</sup> source, 1 N H<sub>2</sub>SO<sub>4</sub> and 1 N NaOH for pH adjustment, and distilled water for dilutions and washing. All glassware was rinsed with distilled water prior to use.

**4.2 Experimental Setup**

Bench-scale batch experiments were conducted in 1 L borosilicate glass beakers placed on a magnetic stirrer. The stirrer speed was maintained at 200 rpm. Temperature was recorded with a calibrated digital thermometer, and pH measured

using a calibrated glass-electrode pH meter. Vacuum filtration (Whatman) was used to separate the oxidized supernatant from the iron-rich sludge. All experiments were performed in triplicate where practical and mean values reported.

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

1. Pre-characterization: The raw composite sample was characterized for pH, BOD<sub>5</sub>, COD, chloride, nitrate, fluoride, turbidity and temperature.



Figure 2: Untreated wastewater (composite influent sample).

2. Acidification: The initial pH ( $\approx 5.8$ ) was lowered to the target pH of 3.0 using 1 N H<sub>2</sub>SO<sub>4</sub> added dropwise while continuously stirring; this pH range promotes efficient formation of •OH radicals while minimizing non-productive peroxide decomposition.

3. Catalyst dosing: Ferrous sulfate solution was prepared and dosed to obtain 10 mg/L Fe<sup>2+</sup> in the reaction mixture. The dose was selected based on preliminary trials and literature precedent for high-strength industrial wastewaters.

4. Oxidant dosing: H<sub>2</sub>O<sub>2</sub> stock was diluted and dosed to reach 100 mg/L working concentration. H<sub>2</sub>O<sub>2</sub> was added slowly (dropwise in several portions) to control exotherm and avoid violent effervescence.

5. Reaction and mixing: The mixture was stirred at 200 rpm for 60 minutes at ambient laboratory temperature ( $\approx 30$ – $33$  °C). Visual observations (gas evolution, color change, odor reduction) were recorded at 5–10 minute intervals.

6. Quenching and neutralization: After reaction completion the mixture was neutralized to pH  $\approx 7.0$ – $7.5$  using 1 N NaOH. Ferric hydroxide precipitate formed and was removed by vacuum filtration. The filtrate was retained for post-treatment analysis.

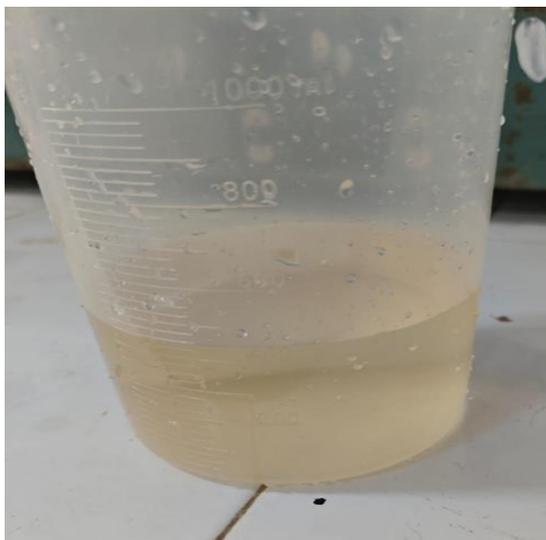


Figure 3: Treated wastewater after Fenton oxidation (neutralized and filtered).

7. Sludge handling: The wet sludge was dried at 105 °C to determine dry mass and qualitatively described (color, texture). Sludge was stored in labeled vials for possible further characterization.

**4.4 Analytical Methods**

Standard analytical methods were followed: pH (digital pH meter), BOD<sub>5</sub> (5-day BOD), COD (closed reflux colorimetric/titrimetric method), chloride, nitrate and fluoride (ion-specific methods as per APHA), turbidity (Jackson turbidity or nephelometric equivalent), and TDS (gravimetric). Quality control included blanks and standard checks.

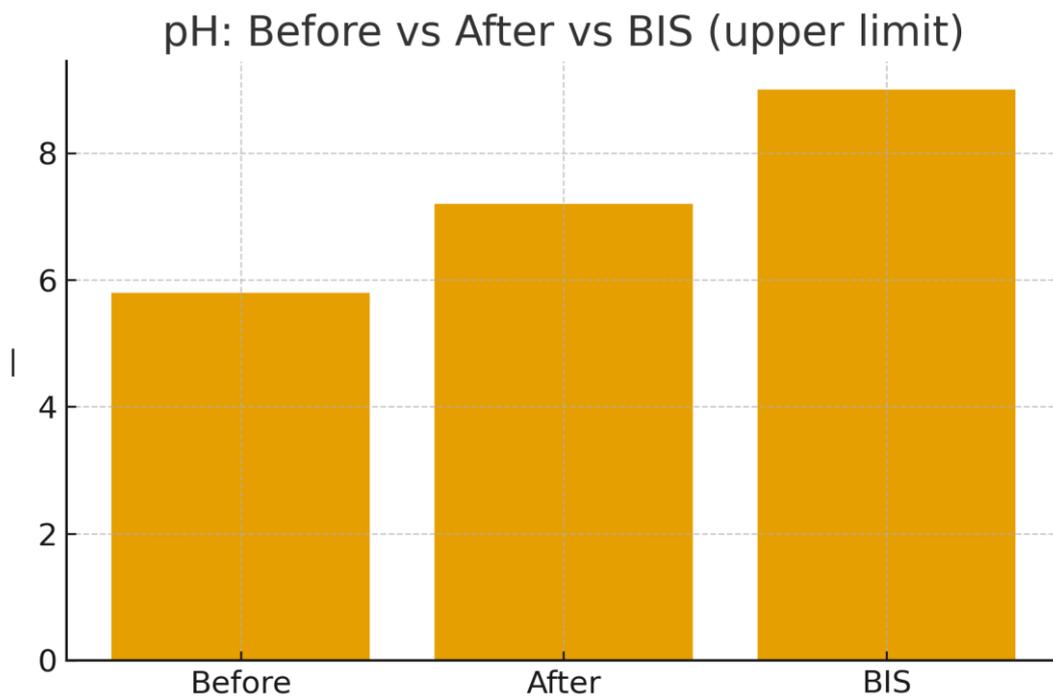
**V. RESULTS AND DISCUSSION**

Table 1 summarizes the measured parameters before and after Fenton treatment and compares them to BIS discharge limits. Percentage reductions are calculated and discussed.

Parameter	Before Treatment	After Treatment	BIS Standard Limit	% Reduction (approx.)
pH	5.8	7.2	6.5–9.0	-
BOD (mg/L)	240	28	≤ 30	88.33%
COD (mg/L)	510	80	≤ 250	84.31%
Chloride (mg/L)	370	310	250–1000	16.22%
Nitrate (mg/L)	42.5	31.5	≤ 10	25.88%
Fluoride (mg/L)	3.7	2.1	≤ 1.5	43.24%
Temperature (°C)	33	32	< 40	3.03%
Turbidity (JTU)	110	10	5–10	90.91%

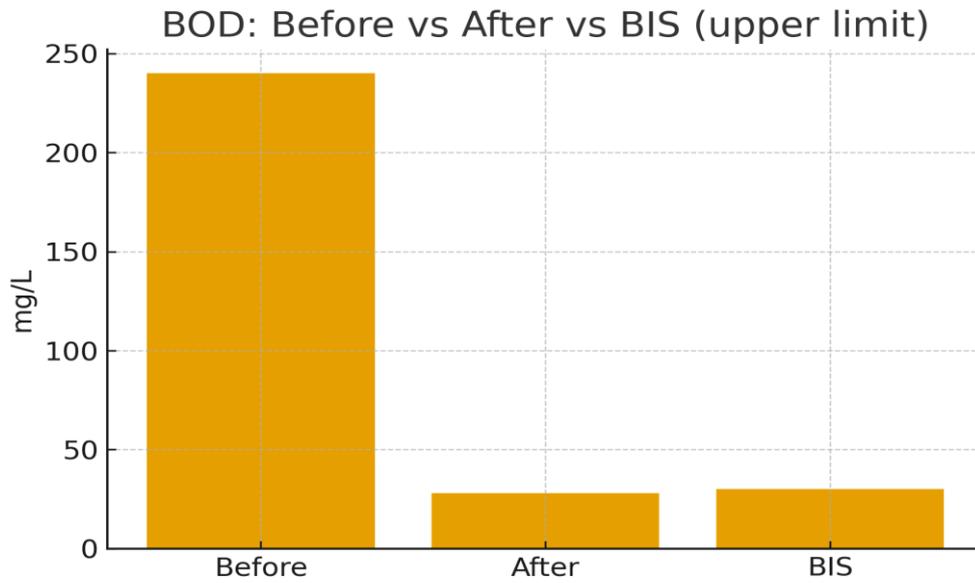
**5.1 Graphical Comparison of Key Parameters**

Figure 4: pH change before and after treatment.



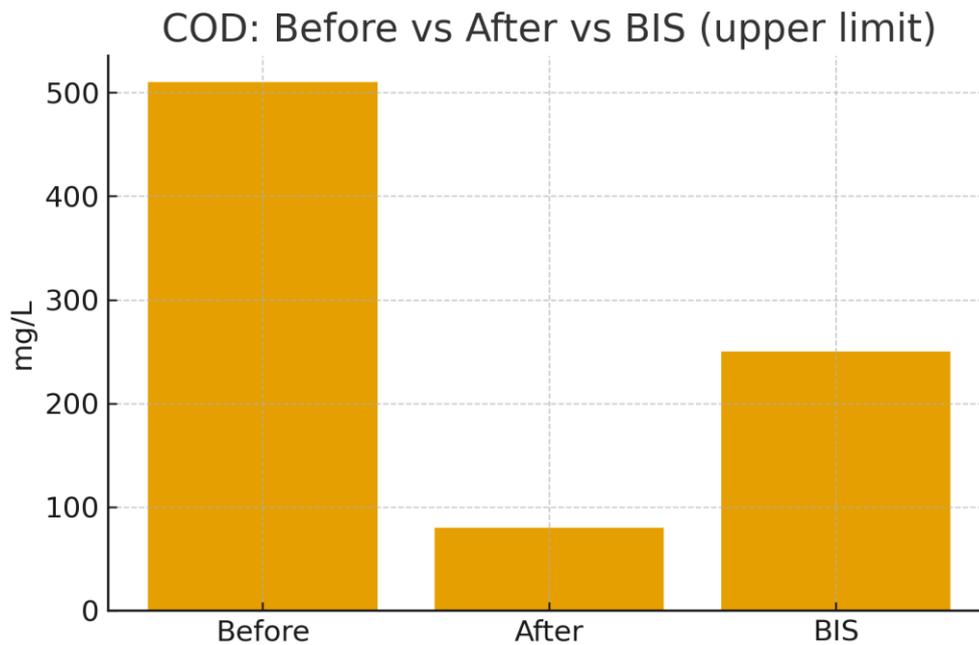
Observation: pH was adjusted from acidic conditions to near-neutral after treatment and neutralization.

Figure 5: BOD (mg/L) before and after treatment.



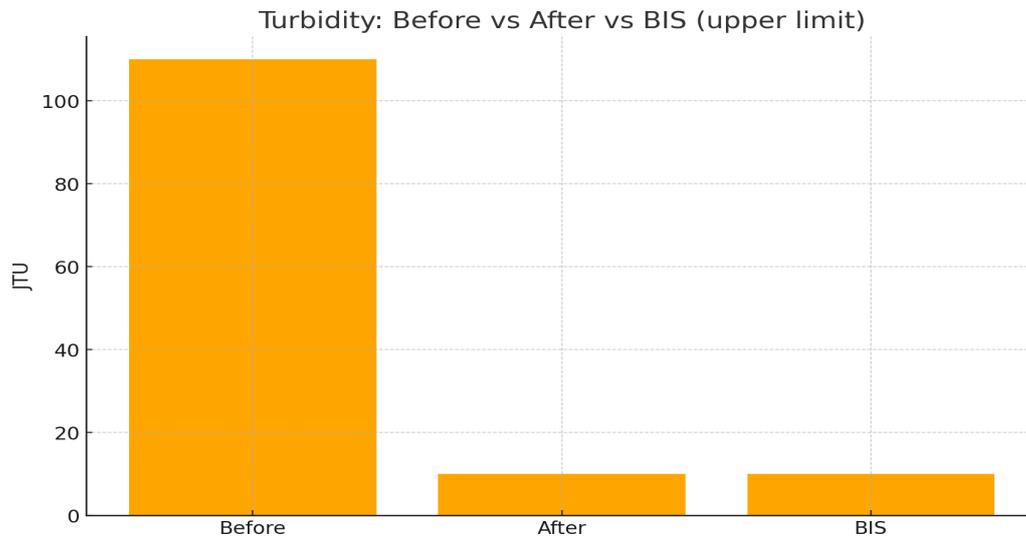
Observation: BOD decreased substantially indicating mineralization of biodegradable organics.

Figure 6: COD (mg/L) before and after treatment.



Observation: COD reduction shows oxidation of refractory organics; final COD meets BIS discharge limits.

Figure 7: Turbidity (JTU) before and after treatment.



Observation: Turbidity dropped markedly, reflecting coagulation/precipitation of suspended solids during Fenton treatment.

### 5.2 Organic Load Reduction (BOD & COD) — Detailed Discussion

The Fenton process achieved a BOD reduction from 240 to 28 mg/L, corresponding to a reduction of 212.0 mg/L (88.33%). COD decreased from 510 to 80 mg/L, a reduction of 430.0 mg/L (84.31%). These values indicate strong mineralization of readily oxidizable organics and substantial oxidation of refractory fractions.

### 5.3 Inorganic Species and Operational Notes

Chloride, nitrate and fluoride showed partial reductions but remained above potable reuse limits. Chloride changed from 370 to 310 mg/L. Nitrate and fluoride decreased but would require ion-specific polishing for potable reuse. Sludge management and peroxide handling are key operational considerations for scaling up.

## VI. CONCLUSION

The homogeneous Fenton oxidation process is validated at bench scale for substantial removal of organic load and turbidity from chemical industry wastewater. The inclusion of photos and graphs in this manuscript provides clear visual evidence of performance and sample quality before and after treatment. Recommendations include pilot-scale trials, techno-economic assessment, and coupling Fenton with downstream polishing for nitrate/fluoride removal.

## REFERENCES

- [1]. APHA (2017). Standard Methods for the Examination of Water and Wastewater (23rd ed.). American Public Health Association.
- [2]. Pignatello, J. J., Oliveros, E., & MacKay, A. (2006). Advanced oxidation processes for organic contaminant destruction based on the Fenton reaction and related chemistry. *Critical Reviews in Environmental Science and Technology*, 36(1), 1–84.
- [3]. Neyens, E., & Baeyens, J. (2003). A review of classic Fenton's peroxidation as an advanced oxidation technique. *Journal of Hazardous Materials*, 98(1–3), 33–50.
- [4]. Babuponnusami, A., & Muthukumar, K. (2014). A review on Fenton and improvements to the Fenton process for wastewater treatment. *Journal of Environmental Chemical Engineering*, 2(1), 557–572.
- [5]. Xu, L., Wang, C., & Zhou, Q. (2020). Advancements in the Fenton Process for Wastewater Treatment: A Review. *Environmental Engineering Science*, 37(8), 503–520.