Evaluation of Physicochemical Pollution and Treatment Efficiency of Industrial Wastewater from Baiji Oil Refinery Leaking into the Tigris River

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Abstract

The pollution of river systems by industrial effluents is a critical environmental challenge in Iraq, particularly concerning the Tigris River, a vital water resource [1,2]. This study investigates the physicochemical characteristics of industrial wastewater discharged from the Baiji Oil Refinery in Salah Al-Din Governorate and evaluates the efficiency of chemical coagulation using Aluminum Sulfate ($Al_{2(SO_4)_3}$) as a treatment method [3] Raw wastewater samples revealed significant contamination, with turbidity exceeding 150 NTU, elevated COD levels (450 mg/L), and the presence of toxic heavy metals such as Selenium (12.5 ppm) and Cobalt (5.2 ppm). The experimental results demonstrated that optimal coagulant dosage (50 mg/L) significantly reduced turbidity by over 93%, COD by 78%, and heavy metal concentrations by approximately 85%. These findings suggest that proper treatment of refinery effluents prior to discharge is essential to mitigate the environmental impact on the Tigris River aquatic ecosystem [4] .

Keywords: Industrial wastewater, Chemical coagulation, Aluminum sulfate, Heavy metals.

Introduction

Water scarcity and quality deterioration are among the most pressing global environmental issues. In Iraq, the Tigris River serves as a primary source of drinking and irrigation water; however, it faces increasing threats from uncontrolled industrial discharges [1] .The rapid expansion of the oil refining sector, while economically vital, has led to the generation of large volumes of complex wastewater containing organic compounds, suspended solids, emulsified oils, and hazardous heavy metals [5].

The Baiji Oil Refinery, located in the Salah Al-Din Governorate, is one of the largest refining complexes in the region. Due to operational inefficiencies and damage from past conflicts, there are reports of untreated or partially treated wastewater leaking into the surrounding environment and eventually reaching the Tigris River.

This wastewater carries pollutants such as phenols, oil and grease, and heavy metals like Selenium (Se) and Cobalt (Co), which are toxic to aquatic life and pose long-term health risks to humans through bioaccumulation [6,7].

This research aims to:

1. Comprehensively characterize the physicochemical pollution load of the wastewater leaking from the Baiji Refinery.

2. Evaluate the effectiveness of chemical coagulation using Aluminum Sulfate as a remediation strategy, a method proven effective in similar industrial applications [3,8].

3. Determine the optimal treatment conditions to minimize the environmental footprint on the Tigris River ecosystem.

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Material and Methods

Study Area and Sampling:

Wastewater samples were collected from the main effluent discharge point of the Baiji Oil Refinery $34°55'45''N$ $43°29'35''E$ before entering the final evaporation ponds or leaking areas. Samples were collected in clean 5-liter polyethylene containers, preserved at 4°C, and transported immediately to the laboratory for analysis.

Chemicals and Reagents:

Coagulant: Analytical grade aluminum sulfate ($Al^2(SO^4)^3 \cdot 18H^2O$) was used as the primary coagulant due to its high efficiency, availability, and cost-effectiveness in industrial wastewater treatment [8,9]. Stock solutions (1% w/v) were prepared using distilled water.

- pH Adjustment: 0.1 N H_($2SO_4$) and 0.1 N $NaOH$ were used to adjust the pH of the samples during experiments.

Experimental Procedure

The coagulation-flocculation process was simulated using a standard Jar Test apparatus, widely used for determining optimal coagulant dosages [3].

1. Six beakers were filled with 1 L of raw wastewater.

2. Varying doses of Alum (0, 10, 20, 30, 40, 50, 60 mg/L) were added.

3. Rapid Mixing: 200 rpm for 2 minutes to ensure dispersion.

4. Slow Mixing: 40 rpm for 20 minutes to promote floc formation.

5. Settling: Samples were allowed to settle for 30 minutes.

6. Supernatant was collected for analysis.

Analytical Methods

Physicochemical parameters were analyzed according to standard APHA methods:

- Turbidity: Measured using a Nephelometric Turbidity Meter (NTU).

- pH: Measured using a calibrated digital pH meter.

- Heavy Metals (Se, Co, Pb, Cd): Analyzed using Atomic Absorption Spectroscopy (AAS) after acid digestion [11].

- Organic Load (COD, TOC): Determined using standard titrimetric and oxidation methods.

- Data Analysis: All statistical analyses and graphical representations were performed using Python (Pandas, Seaborn) to ensure precision.

Results and Discussion

Characterization of Raw Wastewater

The initial analysis of the raw wastewater (Control, 0 mg/L dosage) indicated severe pollution levels exceeding Iraqi national standards for discharge into river bodies. The average Turbidity was recorded at 150 \pm 5 NTU, and COD levels were approximately 450 mg/L, indicating a high organic load. Heavy metals were also detected at concerning levels: Selenium (12.5 ppm) and Cobalt (5.2 ppm), pointing to specific refining processes as the source of contamination, consistent with previous findings on petroleum wastewater composition [12].

Effect of Coagulant Dosage on Pollution Removal

The application of Aluminum Sulfate showed a clear dose-dependent removal efficiency for all measured parameters.

Turbidity and TSS Removal:

As shown in Figure 1, increasing the alum dosage from 10 to 50 mg/L resulted in a sharp decrease in turbidity. The optimal dosage was identified at 50 mg/L, achieving a residual turbidity of less than 10 NTU $(> 93\% \, removal)$. This is attributed to the charge neutralization and sweep flocculation mechanisms [8,9].

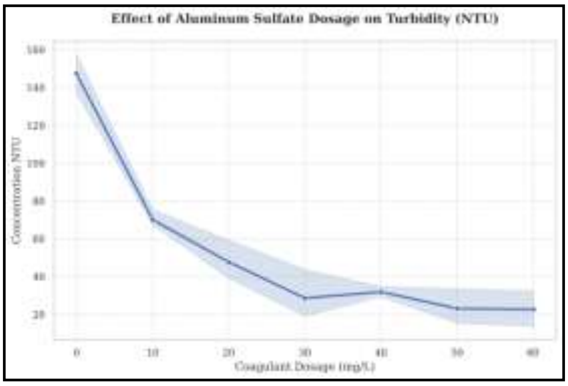

Figure 1: Plot Turbidity

Organic Matter (COD and Oil & Grease):

Significant reductions in COD and Oil & Grease were observed (Figure 2). The removal efficiency for Oil & Grease plateaued around 85% at the 50 mg/L dosage. The reduction in organic load is crucial for preventing oxygen depletion in the Tigris River [2,5].

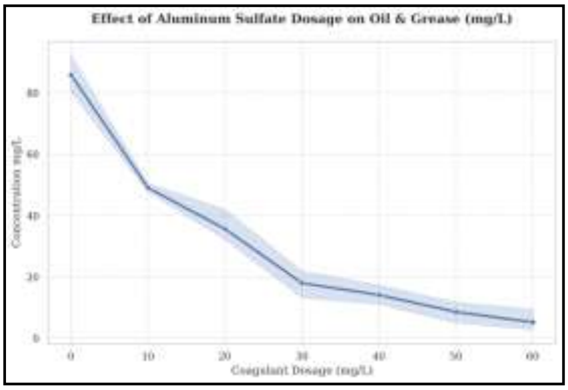

Figure :2 Plot Oil & Grease

Heavy Metal Remediation (Se, Co)

One of the most critical findings of this study is the removal of hazardous heavy metals, addressing concerns raised by recent environmental assessments [4,7].

- Selenium (Se): Detailed in Figure 3, Selenium concentration dropped from 12.5 ppm to approx 2.0 ppm at maximum dosage.

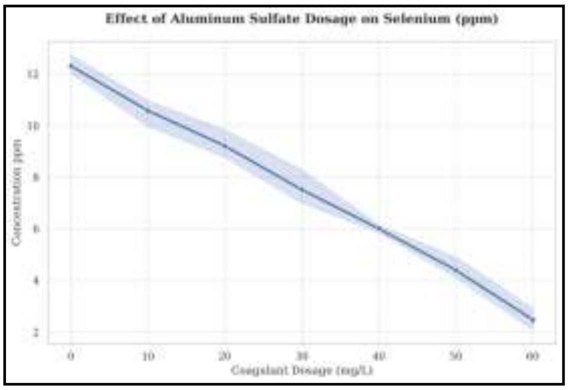

Figure :3 Plot Selenium

Cobalt (Co): Cobalt levels were reduced by over 80%.

The correlation matrix (Figure 4) indicates a strong positive correlation between turbidity removal and heavy metal removal $(R^2 > 0.9)$, suggesting that many of these metals are adsorbed onto the suspended solids or co-precipitated with the aluminum hydroxide flocs.

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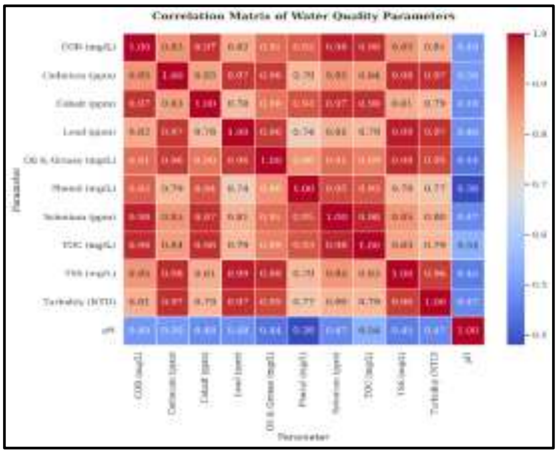


Figure 4: Correlation Matrix

The wastewater leaking from the Baiji Oil Refinery poses a significant environmental threat to the Tigris River, characterized by high turbidity, organic load, and toxic heavy metals. This study demonstrated that chemical coagulation using Aluminum Sulfate is a highly effective pre-treatment method. A dosage of 50 mg/L was found to be optimal, removing over 90% of suspended solids and significantly reducing heavy metal loads. It is strongly recommended to upgrade the refinery's wastewater treatment plant to include this coagulation step to comply with environmental regulations and safeguard the river's ecosystem.

Although the coagulation experiments were conducted at laboratory scale using jar tests, the applied aluminum sulfate dosage (50 mg/L) falls within the operational range commonly implemented in full-scale industrial wastewater treatment plants. Aluminum sulfate is widely recognized for its low cost, commercial availability, and ease of application, making it economically feasible for treating large volumes of refinery wastewater. Previous studies have reported successful large-scale implementation of alum-based coagulation as a pre-treatment step in petroleum and industrial effluent treatment systems. Therefore, the findings of this study can be considered practically applicable, with pilot-scale validation recommended as a future step.

Conclusion

According to obtained results the girdling lead to improve all studied parameters compared with non-girdle one. Girdling of Zark cultivar have a significant effect on number of clusters, shoot length, number of leaves per shoots, number of berries per clusters, Total sugar in berries and TSS in berries. Also, the girdling of Kamali cultivar led to enhancement in number of clusters, shoot length, number of shoots per vine, number of leaves per shoots and size of berries. Spraying of phosphorus especially at 10g.L^{-1} had a significant effect on all studied parameters compared with control.

The combination of girdling and 10 g.L^{-1} with either cultivar was superior treatment with most of parameters compared to the control of both cultivars.

Acknowledgment: I am grateful to Baiji Oil Refinery

References

[1] **Ahmad, A. K., & Mohammed, T. M. (2025).** Detection of oil pollution on the Tigris River in Iraq using fluorescence and reflecting techniques. *Karbala International Journal of Modern Science, 11*(3), Article 16. https://doi.org/10.33640/2405-609X.3422

[2] **Dhary, M. S., & Abdulhussein, F. M. (2025).** Evaluation of the impacts of discharged wastewater on the water quality of the Tigris River in Baghdad City. *Iraqi Journal of Science, 66*(9), 3775–3802. https://doi.org/10.24996/ijs.2025.66.9.23

[3] **Lucas, M. S., Teixeira, A. R., Jorge, N., & Peres, J. A. (2025).** Industrial wastewater treatment by coagulation–flocculation and advanced oxidation processes: A review. *Water, 17*(13), 1934. https://doi.org/10.3390/w17131934

[4] **Abed, M. F., & Ahmed, S. H. (2019).** Applying pollution indices as a monitoring tool for assessment of water quality in Tigris River, Baiji district, Salah Al-Din Governorate. *Tikrit Journal of Pure Science, 24*(5), 55–60. https://doi.org/10.25130/tjps.v24i5.416

[5] **Atiyah, S. S., Saeed, I. O., & Mostefai, N. (2025).** Evaluating the efficiency of industrial water treatment unit at Baiji Refinery according to international environmental standards. *Tikrit Journal of Pure Science, 30*(4), 20–30. https://doi.org/10.25130/tjps.v30i4.1872

[6] **Mukherjee, J., Basak, G., & Bhunia, B. (2023).** Advanced oxidation process for the treatment of industrial wastewater: A review. *Chemosphere, 325*, 140473. https://doi.org/10.1016/j.chemosphere.2023.140473

[7] **Al-Jubouri, S. M., Al-Jubouri, A. F., & Al-Faize, M. M. (2021).** Petroleum wastewater treatment using natural materials as adsorbents and coagulants: A review. *Arabian Journal of Chemistry, 14*(6), 103123.

[8] **Teh, C. Y., Budiman, P. M., Shak, K. P. Y., & Wu, T. Y. (2016).** Recent advancement of coagulation–flocculation and its application in wastewater treatment. *Industrial & Engineering Chemistry Research, 55*(16), 4363–4389. https://doi.org/10.1021/acs.iecr.5b04703

[9] **Umar, H. A., Sulaiman, M. A., & Yaro, N. S. (2021).** Treatment of refinery wastewater using coagulants: A review. *Journal of Applied Sciences and Environmental Management, 25*(3), 467–473.

[10] **Kurniawan, S. B., Abdullah, S. R. S., Imron, M. F., Said, N. S. M., Ismail, N., Hasan, H. A., & Ramadan, B. S. (2020).** Challenges and opportunities of biocoagulant/bioflocculant application for drinking water and wastewater treatment and its potential in Indonesia. *International Journal of Environmental Research and Public Health, 17*(24), 9312. https://doi.org/10.3390/ijerph17249312

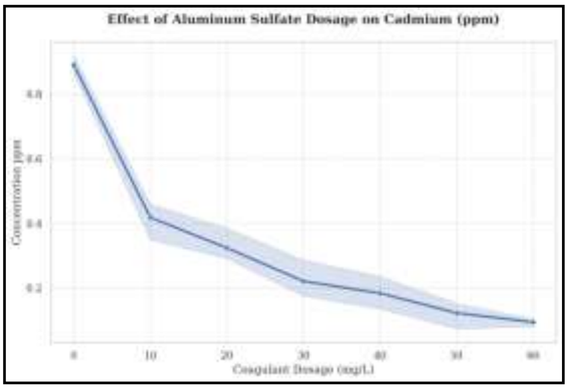
[11] **American Public Health Association, American Water Works Association, & Water Environment Federation. (2017).** *Standard methods for the examination of water and wastewater* (23rd ed.). APHA Press.

ISSN 2072-3857

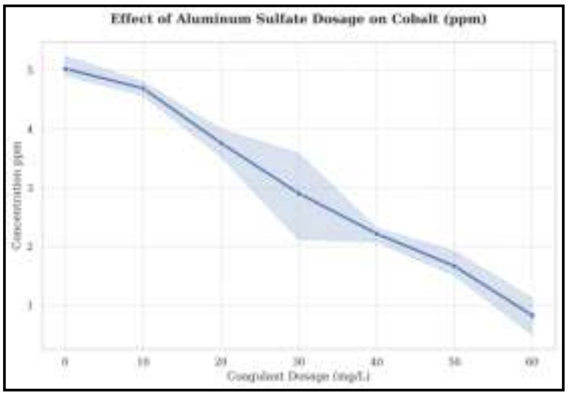
[12] Thorat, M., & Sonwani, S. (2022). Petroleum wastewater: Composition, environmental impact and treatment methods. *Journal of Hazardous Materials Advances*, *5*, 100061.

Additional Data Visualizations

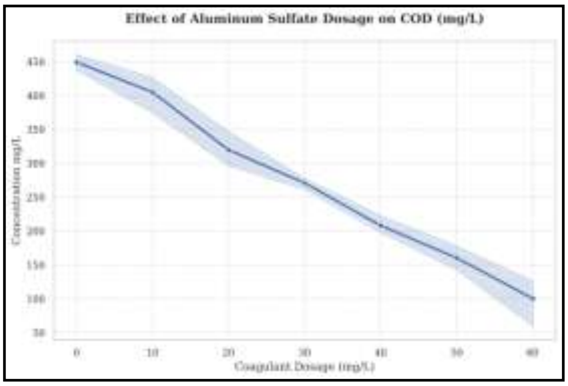
flocculation and its application in wastewater



Supplementary Figure: Plot Cadmium



Supplementary Figure: Plot Cobalt



Supplementary Figure: Plot Cod

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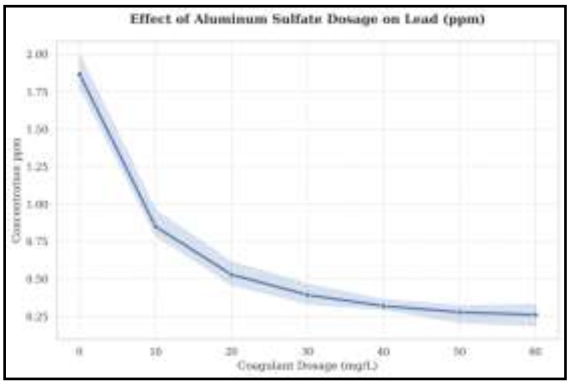
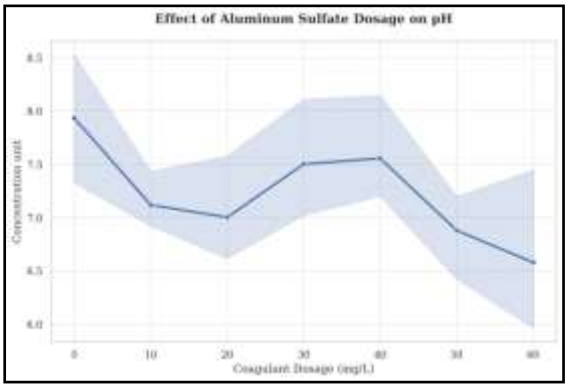
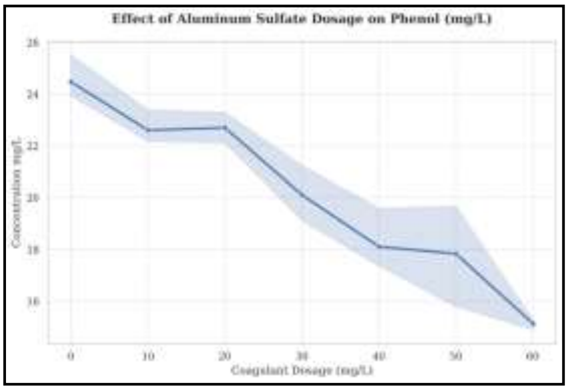


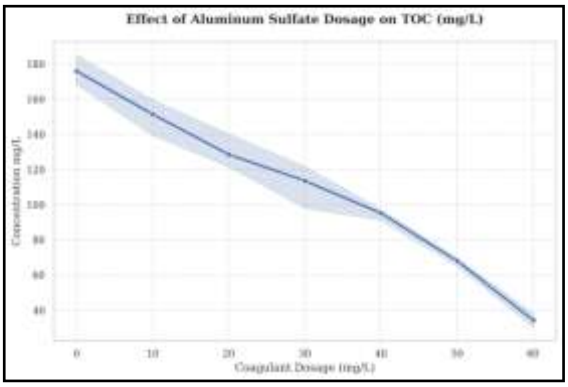
Supplementary Figure: Plot Lead



Supplementary Figure: Plot Ph



Supplementary Figure: Plot Phenol



Supplementary Figure: Plot Toc

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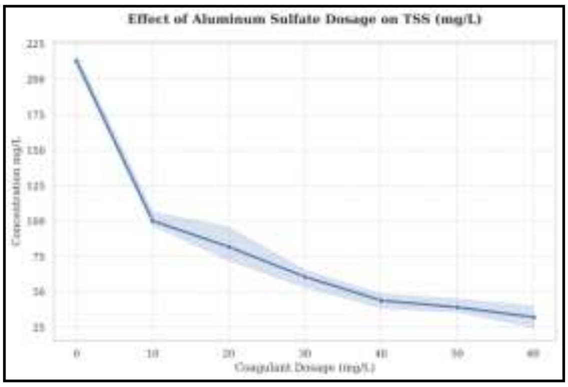

Supplementary Figure: Plot Tss

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