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Optimization of Coagulation–Flocculation Dosing for TSS, BOD and COD Removal from Textile Wastewater: A Case Study of Arbaminch Textile Share Company

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ABSTRACT: The Ethiopian textile industry has experienced rapid expansion as a key focus for industrialization and export. However, this growth has generated substantial wastewater volumes, with over 60% of effluent treatment plants failing to meet national discharge standards for BOD, COD, and TSS. Inefficient coagulant-flocculant dosing practices, often based on trial-and-error approaches, remain a primary contributor to this non-compliance.

This study aimed to optimize coagulation-flocculation dosing for the removal of TSS, BOD, and COD from textile wastewater at Arbaminch Textile Share Company, Ethiopia, to achieve compliance with MoEFCC discharge standards.

Wastewater samples were collected from primary and secondary treatment units. Jar test experiments were conducted to determine optimal pH (5.5–8.0) and coagulant (alum) to flocculant (PAM) dosing ratios (0:0 to 30:8 mL). Treatment efficiency was evaluated through physicochemical analysis of TSS, BOD, and COD before and after optimization.

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Initial wastewater characterization revealed pollutant concentrations substantially exceeding permissible limits. Optimal conditions were identified at 160 mg/L alum, 8 mg/L PAM (20:4 mL ratio), and pH 7.5. These conditions achieved exceptional removal efficiencies: 100% TSS, 90.8% COD, and 92.2% BOD, improving from baseline removals of 82.6% and 87.4% for COD and BOD, respectively. Overdosing provided marginal gains but reduced post-treatment pH below 5.0, increasing costs and sludge production.

Optimized coagulation-flocculation with precise pH control and chemical dosing provides a cost-effective, technically viable primary treatment solution for Ethiopian textile wastewater. The findings offer an evidence-based framework for improving ETP performance, achieving regulatory compliance, and supporting sustainable industrial development.

Keywords: *Textile wastewater, effluent treatment plant, coagulation-flocculation, optimization, pollutant removal efficiency*

1. INTRODUCTION

A primary environmental concern is the vast quantity of wastewater generated from the wet processing stages, which consume huge volumes of water and chemicals (Uddin et al., 2023). Each specific operation contributes its own unique pollutants: desizing releases breakdown products like starches; scouring creates an alkaline waste stream rich in fats and waxes; bleaching contributes residual oxidizing agents; dyeing produces intensely colored water with salts, dyes, and chemicals; and finishing adds surfactants and resins (Holkar et al., 2016; Yaseen & Scholz, 2017). The resulting combined effluent is a complex mixture characterized by extreme pH levels, a high organic load (BOD/COD), suspended solids, and toxic components such as heavy metals and dyes that resist degradation. When released untreated, this pollution blocks sunlight, depletes oxygen, and destroys aquatic life (Wang et al., 2022).

To mitigate these impacts, the coagulation-flocculation process is a basis of primary wastewater treatment. This method involves adding chemicals typically metal salts like alum (aluminum sulfate), along with organic polymers to settling tanks. These chemicals work by first neutralizing the electrical charges that keep fine particles suspended (coagulation), and then binding the neutralized particles together into larger clumps called

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"flocs" (flocculation) (Kallawar & Bhanvase, 2023). These larger, heavier flocs settle much faster, intensively improving the removal of solids, and organic matters.

Ethiopia has made the textile industry a key focus for industrialization and export, establishing major hubs in Hawassa, Kombolcha, and Bahir Dar. The sector currently includes 25 wet processing factories operating outside of industrial parks. Among these, ten facilities use conventional effluent treatment plants, three have achieved zero liquid discharge systems, and twelve operate with only primary or secondary treatment. However, rapid expansion has led to increased wastewater generation, often exceeding the capacity of existing effluent treatment plants (ETPs). Studies have shown that Ethiopian textile effluents contain high levels of BOD, COD, and toxic dyes, frequently exceeding permissible discharge limits, contributing to river pollution and affecting downstream communities (Dadi, 2016; Tafesse & Yetemegne, 2020).

Table 1: National Textile Effluent Discharge Limit Values

Parameter	Limit Values
pH	6 – 9
BOD_5 at $20^{O}C$	90% removal or 50 mg/l, whichever is less
COD (mg O_2 /l)	80% removal or 150 mg/l, whichever is less
Total Suspended solids	30

Source: Provisional National Standards for Industrial Pollution Control in Ethiopia (MEFCC)

A comprehensive gap assessment conducted by Environment Energy & Safety Research & Development Desk in Textile & Garment Industry Research & Development Center across multiple Ethiopian wet processing factories revealed consistent non-compliance with national environmental standards or requirements specifically for BOD, COD, and TSS parameters widely recognized as critical indicators of ETP performance efficiency. According to the gap assessment, more than 60% of textile industries' effluent treatment plants failed to meet discharge requirements. The three-year assessment data showed in Table-2.

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Table-2: List of Effluent Parameters not fulfill the National Requirements of MoEFCC

Parameters	**16 Textile industries test results in three years' experience**					
	2022		**2023**		**2024**	
	Compliance	Non-Compliance	Compliance	Non-Compliance	Compliance	Non-Compliance
TSS	25%	75%	42%	58%	34%	66%
BOD	17%	83%	25%	75%	42%	58%
COD	9%	91%	17%	83%	25%	75%
Color		Colored		Colored		Colored

This situation is compounded by several interrelated deficiencies: imbalanced coagulant-flocculent dosing and pH optimizations; mismatches between ETP design capacity and actual wastewater generation volumes; and the lack of systematic, evidence-based selection procedures for treatment chemicals.

Most empirical studies have focused on laboratory-scale optimization of coagulant dosage and pH, often using synthetic wastewater, with limited application to real effluents from Ethiopian textile industries where wastewater composition is highly variable and often alkaline (Aragaw & Bogale, 2023). Furthermore, advanced optimization techniques remain underutilized in Ethiopia, where dosing practices are often inconsistent and based on trial-and-error. Another gap lies in the weak integration of technical optimization with operational and managerial practices, meaning that even when laboratory results are promising, translation to full-scale effluent treatment plants is limited (Wondim et al., 2021).

Therefore, this research was conducted with the general objective of enhancing the efficiency of effluent treatment plants in selected Ethiopian wet processing textile industries through optimization of coagulant-flocculent dosing and pH adjustment for effective reduction of pollution load. The specific objectives were: (1) to determine the physicochemical characteristics (BOD, COD, and TSS) of wastewater from two selected textile wet processing industries before and after treatment; (2) to optimize the coagulant-

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flocculent dosing ratio and pH level for maximum removal of pollutants using jar test experiments; and (3) to evaluate the removal efficiency of BOD, COD, and TSS under optimized treatment conditions compared to existing plant practices.

The research focused on Arbaminch Textile Share Company; located in the Oromia region near Addis Ababa, Ethiopia. Thus industry was selected based on preliminary assessments indicating inefficient ETP performance and the presence of conventional treatment systems including primary treatment units. The findings of this research are expected to provide practical guidelines for improving ETP performance, reducing pollution loads, and ensuring compliance with national standards and international buyer requirements, thereby contributing to environmental sustainability and enhanced export competitiveness of Ethiopian textile products.

2. RESEARCH METHODOLOGY

2.1. Materials and Reagents

2.1.1. Wastewater Sample

The study utilized raw influent textile wastewater collected from the Arbaminch Textile Share Company. A purposive sampling design was adopted to ensure the selection of representative sampling points within the industry's effluent treatment plant. Wastewater samples were collected from three locations: primary inlet (S_1), primary outlet (S_2), and secondary outlet (S_3). To account for temporal and spatial variability in effluent quality, composite sampling techniques were employed. Sampling was conducted in two consecutive rounds following corrective maintenance activities to ensure operational stability, with samples collected precisely at the midpoint of discharge events to maximize representativeness.

Table 3: Sampling Design

Textile Factory	Treatment Level	Sampling Points	Number of Samples in 2 Rounds
Arbaminch	Primary & secondary	S_1,S_2,S_3	6
Total			6

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All samples were collected in 2-liter capacity sterilized bottles, preserved at 4°C, and transported to the laboratory for analysis within 24 hours. All sampling procedures and preservation methods were carried out in strict accordance with the *Standard Methods for the Examination of Water and Wastewater* (APHA, 2017).

2.1.2. Chemicals and Reagents

All chemicals used were of industrial grade. Aluminum sulfate (alum, $Al_2(SO_4)_3 \cdot 18H_2O$) was employed as the primary coagulant, while cationic polyacrylamide (PAM) served as the flocculent aid. The pH of the wastewater samples was adjusted using 0.1 N sulfuric acid (H_2SO_4) and 0.1 N sodium hydroxide (NaOH). Distilled water was utilized for the preparation of all reagent solutions and for rinsing glassware. All working solutions were freshly prepared prior to each experimental run to prevent degradation and ensure consistency.

2.1.3. Equipment and Apparatus

The experimental setup included the following instruments and glassware:

- A standard six-paddle jar test apparatus for coagulation–flocculation trials;
- A digital pH meter (calibrated daily) for accurate pH measurement and adjustment;
- A BOD incubator for biochemical oxygen demand determination;
- A COD digestion apparatus for chemical oxygen demand analysis;
- An analytical balance (precision ±0.0001 g) for reagent weighing;
- A laboratory oven for drying samples;
- A refrigeration unit (4 °C) for sample preservation;
- Standard volumetric glassware, including beakers, pipettes, and burettes; and
- Whatman filter papers (grade 42) for sample filtration prior to analysis.

2.1.4. Preparation of Stock Solutions

Stock solutions of coagulant and flocculent were prepared fresh within 24 hours of use to maintain chemical effectiveness. A 8g/L solution of alum was prepared by dissolving 8g of $Al_2(SO_4)_3 \cdot 18H_2O$ in distilled water and diluting to 1 liter. A 1 g/L solution of polyacrylamide (PAM) was prepared by dissolving 1 g of PAM in distilled water and diluting to 1 liter, with gentle stirring to prevent formation of lumps.

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2.2. Experimental Procedure

2.2.1. Optimization of operating pH

To determine the optimal pH for the coagulation-flocculation process, a series of batch experiments were conducted using a standard six-jar apparatus. A 0.5 L volume of homogenized textile wastewater was dispensed into each of the six beakers. The initial pH of the samples was adjusted to target values of 5.5, 6.0, 6.5, 7.0, 7.5, and 8.0 using dilute H_2SO_4 or NaOH under continuous stirring. Following pH adjustment, a constant, pre-determined dosing composition of alum (coagulant) combined with PAM (flocculent) was added to all samples. The mixing procedure comprised a rapid mix phase (1 minute at 120 rpm) to facilitate coagulant dispersion, followed by a slow mix phase (20 minutes at 30 rpm) to promote flocculation. The effectiveness of each pH condition was assessed based on the qualitative characteristics of floc formation (size, density, and settling velocity) and color removal efficiency.

Table-4: Determination of pH by Conducting Jar test

Jar No	Arbaminch Textile Share Company		
	pH value	Floc formed	Color removal
Jar-1	5.5	Not good	No change
Jar-2	6	Good	Not Good
Jar-3	6.5	Very good	Good
Jar-4	7	Very good	Very good
Jar-5	7.5	Excellent	Very good
Jar-6	8	Very good	Very good

The results for Arbaminch Textile Share Company (Table-4), very good floc formation was observed at pH 6.5, 7.0, and 8.0, while excellent results were specifically noted at pH 7.5 whereas color removal efficiency was consistently very good within the pH 7.0 to 8.0 ranges. Thus, maintaining pH between 7 and 7.5 typically yields the best balance between charge neutralization and polymer bridging, resulting in excellent floc formation and enhanced color removal (Ahmed et al., 2021).

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2.2.2. Optimization of Coagulant-Flocculent Dosage

Following the identification of the optimum pH, a second set of jar tests was performed at this fixed pH to establish the most effective chemical dosing ratio. A 0.5 L sample was added to each of the six beakers, and the pH was adjusted to the previously optimized value. Six distinct volumetric dosing combinations of alum (coagulant) and PAM (flocculent) were evaluated, specifically: 0:0, 10:2, 15:3, 20:4, 25:6, and 30:8 mL. The same rapid mixing, slow mixing, and settling protocol was applied to all dosage combinations. Post-settling, the supernatant was analyzed to determine the treatment performance for each dosage ratio.

Table-5: Optimization of Coagulant-Flocculent Dosing Ratio using jar test

Jar Test Composition	**Arbaminch Textile Share Company**	
	Floc formed	Color removal
Composition-1	No change	No change
Composition-2	Fair	Not good
Composition-3	Good	Good
Composition-4	Very good	Very good
Composition-5	Excellent	Very good
Composition-6	Very good	Good

Among the tested compositions shown table 5, Composition-4 (20 mL (160mg) Alum + 4 mL (4mg) PAM)) or (160mg Alum + 4mg PAM) demonstrated the most effective floc formation and color removal at pH 7.5. Collectively, the results from Tables 4 and 5 indicate that Composition-4 (20:4 mL), applied within a pH range of 6.5 to 8.0, provides the optimal balance between treatment performance, cost-effectiveness, and environmental safety.

Comparisons between Composition-4 and Composition-5 (25 mL alum + 6 mL PAM) revealed that although Composition-5 achieved slightly higher removal efficiencies, it required greater chemical consumption and resulted in a post-treatment pH below 5. Such

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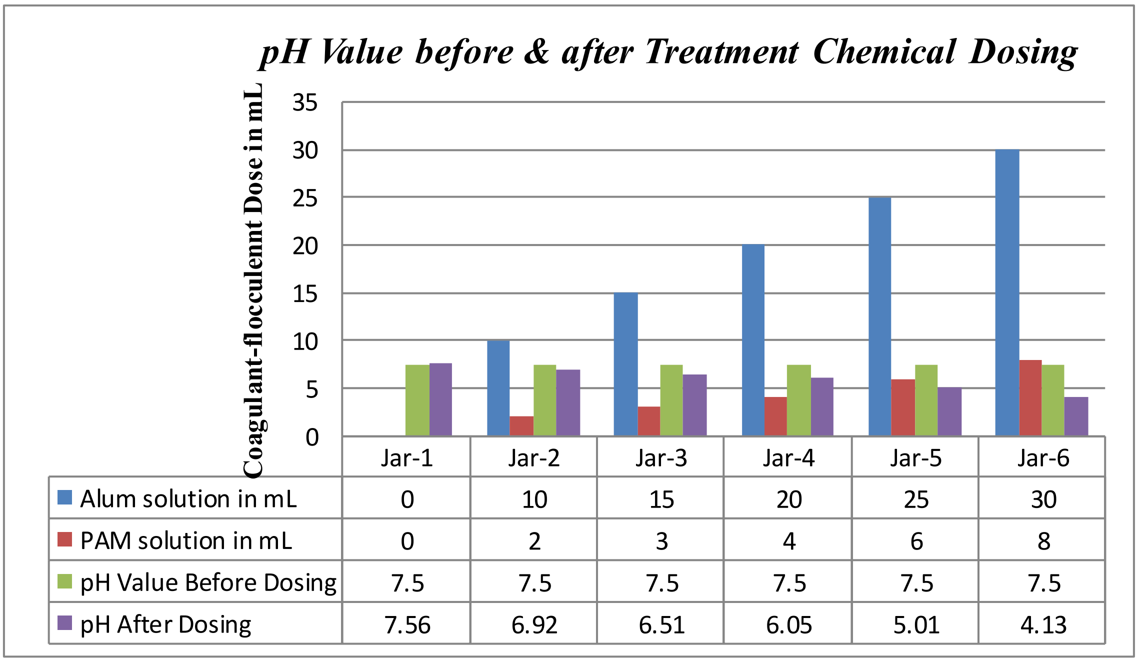
overdosing not only increases operational costs but also risks secondary pollution and challenges in sludge management (Verma et al., 2012; & Šćiban et al., 2018).Collectively, the results from Tables 8 and 9 indicate that Composition-4 (20:4 mL), applied within a pH range of 6.5 to 8.0, provides the optimal balance between treatment performance, cost-effectiveness, and environmental safety. This condition achieved rapid sedimentation, effective color removal, and reductions in BOD, COD, and TSS. Importantly, maintaining near-neutral pH ensures compliance with discharge standards and minimizes ecological risks. Therefore, textile industrial effluents should be treated using optimized alum with PAM dosing before discharge to prevent water and soil pollution.



	Jar-1	Jar-2	Jar-3	Jar-4	Jar-5	Jar-6
Alum solution in mL	0	10	15	20	25	30
PAM solution in mL	0	2	3	4	6	8
pH Value Before Dosing	7.5	7.5	7.5	7.5	7.5	7.5
pH After Dosing	7.56	6.92	6.51	6.05	5.01	4.13

Figure 1: pH value before and after Dosing of Alum with PAM

2.2.3. Treatment Efficiency Calculation

The efficiency of chemical treatment processes was calculated by using the following formula:

% Reduction in pollution load $= \frac{Ci - Cf}{Ci} * 100$ ………………………………….. (1)

Where: C_i = initial concentration before treatment

C_f = final concentration after treatment

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2.3. Methods of Data Analysis

The physico-chemical data obtained from wastewater samples were analyzed using descriptive statistical methods. Descriptive statistics (means, standard deviations) were computed to establish baseline values and characterize treatment performance. Results were presented using tables and figures to facilitate interpretation and comparison with national discharge standards established by the Ministry of Environment, Forest and Climate Change (MoEFCC).

2.4. Quality Assurance and Quality Control

To ensure data validity and reliability, the following measures were implemented: (1) all instruments were calibrated before use; (2) reagent blanks were analyzed to correct for background contamination; (3) samples were analyzed in triplicate and mean values reported; (4) standard solutions were used for instrument verification; (5) all glassware was thoroughly cleaned with non-ionic detergent, rinsed with distilled water, and dried before use; (6) sample preservation and storage followed APHA guidelines to prevent degradation; and (7) control experiments were conducted without coagulant addition to establish baseline conditions.

2.5. Ethical Considerations

Prior to data collection, permission was obtained from the management of participating textile factories. Confidentiality of industry-specific operational information was strictly maintained. Wastewater sampling and laboratory experimentation were conducted in compliance with environmental safety protocols to prevent harm to researchers, workers, and the surrounding community. The findings of this research are intended to promote sustainable industrial practices and environmental protection.

3. RESULTS AND DISCUSSION

3.1. Initial Wastewater Characterization

The physicochemical characterization of the raw textile wastewater from Arbaminch Textile Share Company revealed significant pollution loads requiring treatment. The initial TSS, COD, and BOD values (Figures 2, 3 & 4) were substantially elevated, consistent with the characteristics of textile effluents reported in the literature. Textile wastewater is

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typically characterized by high suspended solids, chemical oxygen demand, biochemical oxygen demand, color, and turbidity (Ali et al., 2016; Tesfay, (2019) & Tasneem et al., 2021). The direct discharge of such untreated effluent poses severe environmental and health risks, as these pollutants can damage aquatic ecosystems and reduce surface water quality (Ali et al., 2016 & Karam et al., 2021).

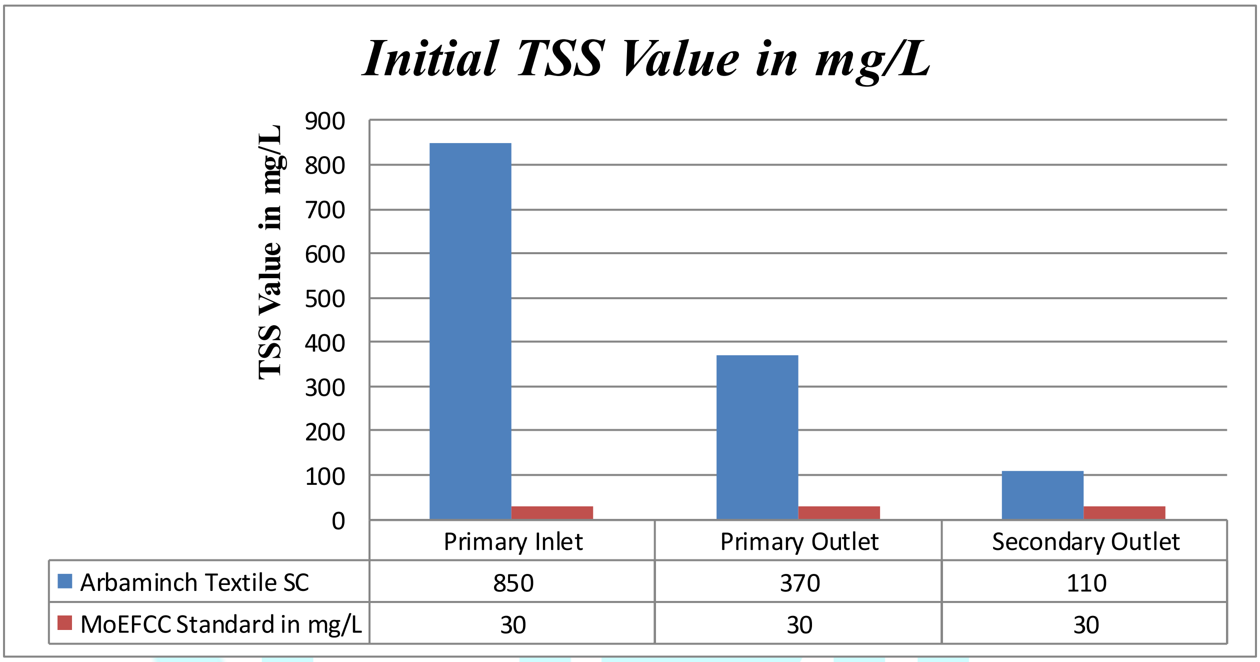

Figure 2: Initial TSS test results of wastewater samples

The initial TSS results (Figure 2) indicate a high suspended solids load in the raw effluent. This is consistent with findings from other textile industry studies, where suspended solids in raw effluents often exceed permissible discharge limits of ≤30 mg/L set by the Ethiopian Ministry of Environment, Forest & Climate Change (MoEFCC), indicating a need for process optimization.

High TSS levels in textile wastewater are commonly associated with suspended dyes, fibers, and chemical residues from processing operations (Verma et al., 2012). Elevated TSS not only reduces water clarity but also increases turbidity, blocks sunlight penetration, and disrupts aquatic ecosystems (Khandegar & Saroha, 2013).

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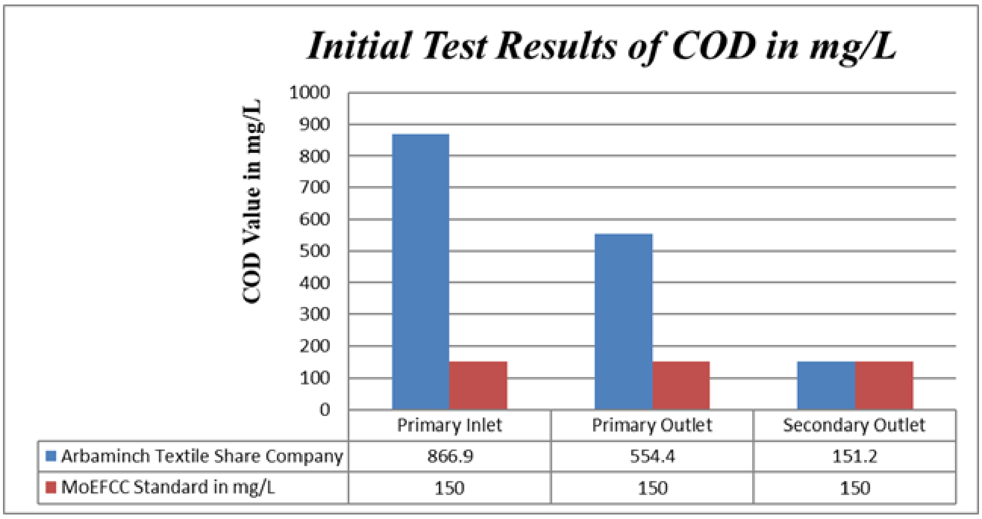

Figure 3: Before optimization COD values in Wastewater Samples

Similarly, the initial COD values (Figure 3) were elevated, reflecting the presence of both biodegradable and recalcitrant organic compounds, including dyes, detergents, and auxiliary chemicals used in textile processing (Verma et al., 2012). High COD not only signals poor effluent quality but also poses risks to aquatic ecosystems by depleting dissolved oxygen and impairing microbial activity (Ali et al., 2016).

The initial BOD measurements (Figure 4) further confirm the organic strength of the wastewater. As noted by Samir et al. (2025), textile effluents are typically characterized by low biodegradability, reflected in a low BOD/COD ratio. This low ratio suggests that biological treatment alone would be insufficient and that physicochemical treatment, such as coagulation-flocculation, is necessary as a primary or pre-treatment step (Samir et al., 2025 & Marques et al., 2025).

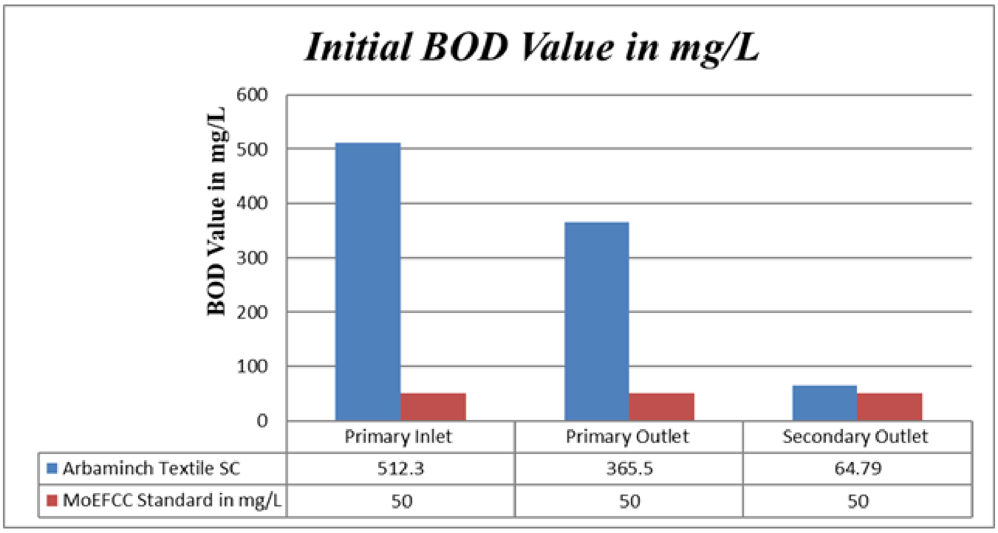

Figure 4: Before Optimizations BOD test results in the Wastewater Samples

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3.2. Performance of Coagulation-Flocculation Treatment

3.2.1. Total Suspended Solids (TSS) Removal

The coagulation-flocculation process demonstrated substantial TSS removal efficiency. Comparison of Figure 1 (initial TSS) and Figure 2 (after treatment) shows a marked reduction in suspended solids concentration following optimization of coagulant and flocculant dosing. This observation aligns with well-established principles of coagulation-flocculation, where the addition of coagulants neutralizes the negative charges of suspended particles, allowing them to aggregate into larger flocs that can be removed by sedimentation (Karama et al., 2021 & Martín et al., 2011).

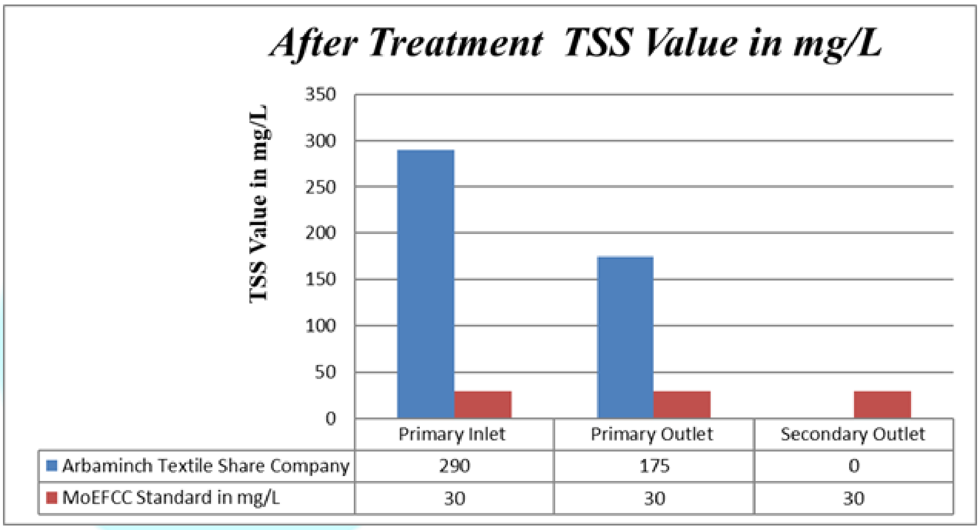

Figure 5: After treatment TSS test results of the Wastewater Samples

Studies have reported TSS removal efficiencies ranging from 73% to over 90% depending on coagulant type, dosage, and operating conditions (Tesfay, 2019; Karama et al., 2021 & Rendana et al., 2025). For instance, Karama et al. (2021) demonstrated the effectiveness of ferric chloride ($FeCl_3$) in removing TSS from real textile wastewater, achieving significant reductions under optimum conditions of pH 9, with 150 rpm rapid mixing for 1 minute, followed by 30 rpm slow mixing for 20 minutes and 30 minutes settling.

3.2.2. Chemical Oxygen Demand (COD) Removal

The COD removal efficiency after coagulant and flocculant optimization (Figure 6) reflects the effectiveness of the treatment in reducing the organic pollutant load. The observed reduction is consistent with findings from numerous studies on textile wastewater

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treatment by coagulation-flocculation. Samir et al. (2025) reported that a combined coagulation-flocculation and column adsorption process achieved 94% COD removal from textile washing wastewater. The study on Moringa oleifera-based coagulants achieved COD removal of up to 29%, with the optimum MO dosage ranging from 20 to 25 g/L (Rendana et al. (2025).

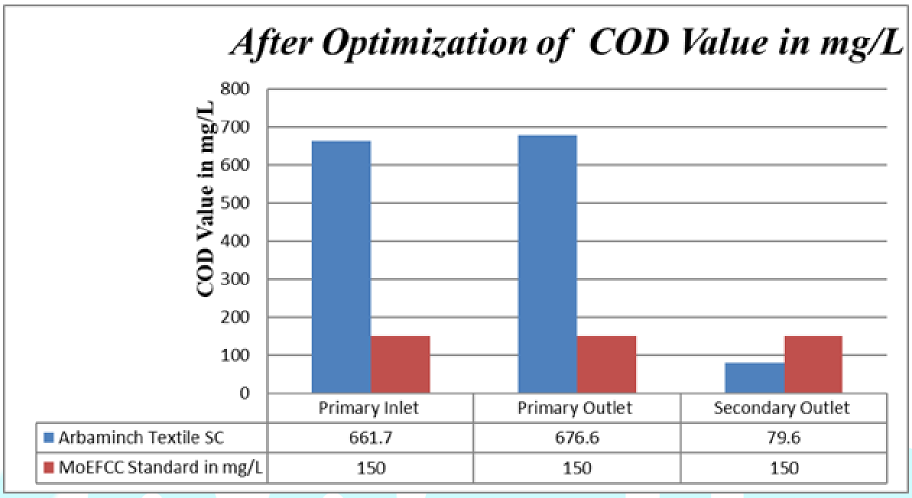

Figure 6: COD test results after coagulant and flocculent optimizations

The COD removal achieved in this study is particularly important given the recalcitrant nature of textile wastewater contaminants. As highlighted by Karama et al. (2021), dyes in textile wastewater contain complex aromatic molecular structures with chromophore groups, making them resistant to biodegradation. Coagulation-flocculation effectively addresses this challenge by removing suspended and colloidal organic matter, thereby reducing the overall COD load before subsequent treatment stages (Karama et al., 2021 & Marques et al., 2025).

Previous studies have shown that alum, when combined with polyacrylamide, can significantly reduce organic matter by destabilizing colloids and facilitating their removal (Du et al., 2014; Pivokonský et al., 2022). Furthermore, optimization of coagulant-flocculent dosing and pH control can enhance COD removal efficiency (Pivokonský et al., 2022).

3.2.3. Biochemical Oxygen Demand (BOD) Removal

The BOD reduction observed after optimization (Figure 7) demonstrates the treatment's ability to remove biodegradable organic matter. The BOD removal pattern aligns with

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studies on textile wastewater treatment, where coagulation-flocculation typically achieves moderate to high BOD reduction. Research by Martín et al. (2011) reported BOD removal of approximately 50% using coagulation-flocculation, which, while significant, was not sufficient to meet local standards in some cases.

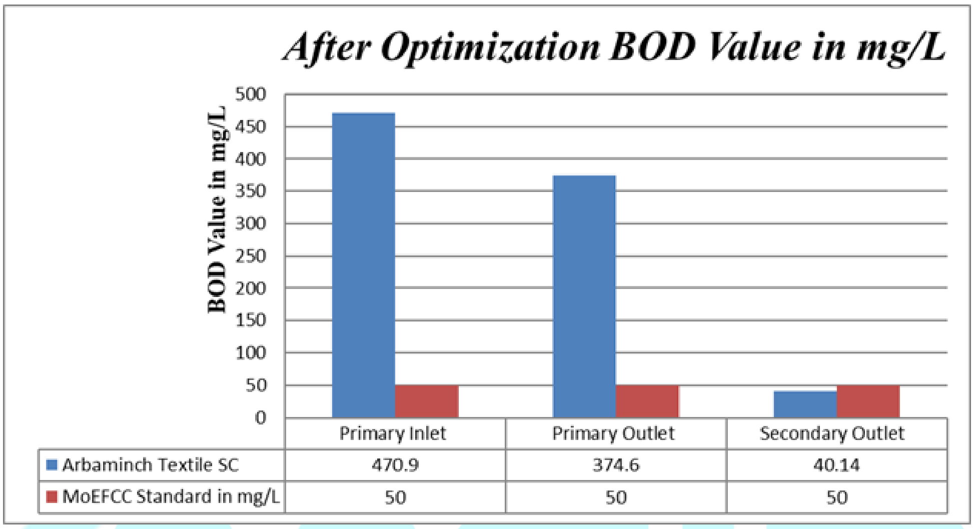

Figure 7: After Optimization BOD test results of the Wastewater Samples

The BOD/COD ratio is an important indicator of wastewater biodegradability. Textile wastewater often exhibits low BOD/COD ratios, indicating the presence of recalcitrant compounds that resist biological degradation (Samir et al., 2025). Coagulation-flocculation improves this ratio by preferentially removing suspended and colloidal organic matter, making the effluent more amenable to subsequent biological treatment if needed (Marques et al., 2025).

The BOD removal efficiency observed in this study is comparable to results from other coagulation-flocculation investigations. Studies using various coagulants, including aluminum sulfate (alum), polyaluminum chloride (PAC), and ferric chloride, have reported BOD reductions ranging from 50% to over 90% depending on operating conditions (Rendana et al., 2025 & Tasneem et al., 2021). For instance, research on Moringa oleifera-based coagulants achieved BOD removal of approximately 16% to 50%; while hybrid treatment approaches combining coagulation-flocculation with other processes have reported BOD removal exceeding 90% (Tasneem et al., 2021; Rendana et al., 2025 & Marques et al., 2025).

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In summary, the optimization of the treatment process led to exceptional pollutant reductions. Total Suspended Solids (TSS) were completely eliminated, achieving 100% removal efficiency and full compliance with MoEFCC discharge standards. Chemical Oxygen Demand (COD) removal improved from 82.6% to 90.8%, demonstrating the strong synergistic effect between alum and PAM in enhancing coagulation performance. Likewise, Biochemical Oxygen Demand (BOD) reduction increased from 87.4% to 92.2%, indicating improved biodegradability and overall effluent quality. At the optimum conditions a coagulant (alum) dose of 160 mg/L, flocculant (PAM) dose of 8 mg/L, and near-neutral pH (7 to 7.5), the removal of TSS, BOD, and COD was maximized, confirming that precise chemical dosing and pH control are essential for achieving high treatment efficiency, regulatory compliance, and environmental protection.

4. CONCLUSION and RECOMMENDATION

4.1. CONCLUSION

This study successfully optimized coagulation-flocculation conditions for treating textile effluent from Arbaminch Textile Share Company to meet Ethiopian Ministry of Environment, Forest and Climate Change (MoEFCC) discharge standards. Raw effluent characterization confirmed severe contamination, with TSS, COD, and BOD levels exceeding regulatory thresholds and posing substantial environmental and public health risks.

Systematic jar testing identified optimal operational parameters as 160 mg/L alum and 8 mg/L polyacrylamide (PAM) at a near-neutral pH of ~7.5. These conditions achieved exceptional performance: complete TSS removal (100%), 90.8% COD removal, and 92.2% BOD removal. Maintaining a near-neutral pH ensured regulatory compliance without requiring post-treatment neutralization. Crucially, the research highlighted the risks of improper dosing; while chemical overdosing yielded minor removal gains, it depressed pH below 5.0, increased operational costs, and generated excessive sludge. Conversely, underdosing led to poor floc formation and incomplete pollutant removal.

These findings address a critical operational gap, as over 60% of Ethiopian textile effluent treatment plants currently fail discharge standards due to unoptimized chemical dosing. By establishing a precise, evidence-based dosing protocol, this work demonstrates that properly managed coagulation-flocculation provides a cost-effective and reliable primary

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treatment solution. Ultimately, transitioning from empirical trial-and-error to systematic optimization supports Ethiopia's industrialization goals while safeguarding water resources and public health.

4.2. RECOMMENDATION

Based on the findings and conclusions of this research, the following recommendations are proposed for improving effluent treatment plant performance in Ethiopian textile industries:

- Textile industries should adopt the optimized coagulant-flocculant dosing ratio of 20:4 mL (160 mg/L alum + 8 mg/L PAM) as a baseline for treating wastewater with similar characteristics to those observed at Arbaminch Textile Share Company. However, industries should conduct their own jar test experiments to fine-tune dosing parameters based on their specific wastewater composition and variability.
- Industries should implement regular monitoring of influent and effluent quality parameters, with particular attention to pH adjustment. Maintaining the pH within the range of 7.0 to 7.5 during coagulation-flocculation is critical for achieving optimal treatment performance and ensuring compliance with discharge standards.
- Given the inherent variability in textile wastewater quality due to changes in production processes, dye types, and chemical usage, industries should conduct periodic jar test experiments (at least quarterly) to reassess optimal dosing conditions and adapt to changing wastewater characteristics.

5. Data Availability Statement

All data generated or analyzed during this study are included within this published article. This includes all figures, tables, detailed experimental procedures (jar test protocols, pH optimization, coagulant-flocculent dosing), and raw analytical results for pH, BOD, COD, and TSS. No supplementary files are available, and no additional external datasets were generated or analyzed during this study.

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