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REDUCTION OF BOD, COD, AND PHYSICOCHEMICAL PARAMETERS IN TANNERY WASTEWATER VIA COAGULATION OF TANNERY DELIMING EFFLUENT

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Abstract

Tannery effluent is a significant environmental pollutant, posing severe ecological threats due to its high levels of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), turbidity, and conductivity. This study explores an alternative approach to treating tannery effluent, focusing on coagulation as a treatment method. Specifically, deliming wastewater was utilized as a coagulant to treat dyeing and fat liquor wastewater. The results demonstrated substantial removal efficiencies, with reductions of BOD, COD, TDS, turbidity, and conductivity at 79.02%, 85.38%, 83.03%, 91.49%, and 83.52%, respectively, when dyeing and deliming wastewater were combined in a 1:2 ratio. Additionally, the coagulation of deliming and fat liquoring wastewater at a 1:1 ratio achieved reductions of 97.15%, 88.46%, 83.62%, 93.63%, and 83.89% in BOD, COD, TDS, turbidity, and conductivity, respectively. Optimum condition was found by mixing deliming and dyeing wastewater and deliming and fat liquoring wastewater at different proportion. This study conclusively demonstrates that deliming wastewater can effectively treat dyeing and fat liquoring wastewater, offering a promising solution for mitigating the environmental impact of tannery effluents.

Keywords

Dyeing, Deliming, Wastewater, Coagulation, Fat liquoring, Tannery, Wastewater.

1. Introduction

The leather and textile industries play a crucial role in global manufacturing, contributing significantly to the economy. However, these industries are also significant sources of industrial pollution, particularly in developing countries like Bangladesh with less stringent environmental regulations and treatment facilities (Bhardwaj *et al*., 2023). Wastewater generated from textile dyeing and tannery processes contains high levels of toxic and non-biodegradable substances that, if untreated, can severely harm aquatic ecosystems and public health. Approximately 30-35 m^3 waste water is discharge during one ton of raw skin or hides processing (Hossain *et al*., 2022; Hossain *et al*., 2024). Around 250 tanneries are situated at Hazaribagh, Saver area and daily discharged waste water is about 22000 m^3. Thus, easily deteriote the physicochemical parameters which collectively represent the wastewater's harmful potential to natural water bodies (Bhardwaj, *et al*., 2023; Hossain *et al*., 2022, 2024; Chiampo, *et al*., 2023; Schranu, *et al*., 2004). Dyeing wastewater from the textile industry is typically characterized by a high concentration of synthetic dyes, salts, and other auxiliary chemicals used during the dyeing process (Hossain, *et al*., 2023). These substances are often resistant to biodegradation and can persist in the environment, causing long-term pollution. The synthetic nature of these dyes also poses risks to aquatic life, as they may reduce light penetration in water bodies, affecting photosynthesis and overall ecosystem balance (Bhardwaj, *et al*., 2023; Hossain, *et al*., 2023). The fat liquor effluent from tannery operations further complicates wastewater treatment efforts, as it contains a complex mixture of oils, fats, surfactants, and various organic and inorganic chemicals. Combining these factors makes treating dyeing and fat liquor wastewater a challenging endeavor, requiring effective strategies to mitigate environmental impacts (Gadlula, *et al*., 2019). Conventional wastewater treatment methods, such as biological treatment, are often insufficient for removing the high concentrations of pollutants found in industrial effluents (Bhardwaj, *et al*., 2023). Biological methods tend to need help with the removal of synthetic dyes and heavy metals due to their recalcitrant nature. As a result, there is a growing need for advanced treatment technologies that can handle the complexities of industrial wastewater. Various Physicochemical waste water treatment using different technologies such as adsorption (Hossain, *et al*., 2023), electrocoagulation (Tahir, *et al*., 2007), ion exchange (Fernando *et al*., 2009), coagulation-flocculation (Tiravanti, *et al*., 2009) have been widely applied in recent years to address the limitations of biological treatments (Bhardwaj, *et al*., 2023; Hossain *et al*., 2022). Coagulation is a well-established technique used to remove suspended solids, organic matter, and colloidal particles from wastewater by adding a coagulant that promotes the aggregation of particles into larger flocs. These flocs can then be removed through sedimentation or filtration. Coagulation has proven effective for treating various industrial effluents, but choosing coagulants is critical to its success (Bhardwaj, *et al*., 2023).

Traditional coagulants, such as aluminum sulfate (alum) and ferric chloride, are widely used but often have drawbacks, including high costs, the generation of large volumes of sludge, and potential secondary pollution due to residual chemicals (Bhardwaj, *et al*., 2023; Saritha, *et al*., 2011). The leather industry generates substantial amounts of wastewater, especially during the deliming stage of leather processing (Bhardwaj, *et al*., 2023). Deliming wastewater contains high levels of calcium hydroxide ($Ca(OH)_2$) and other alkaline substances, which have the potential to act as coagulants (Bhardwaj, *et al*., 2023; Tiravanti, *et al*., 2009). This creates an opportunity for an integrated treatment approach, where wastewater from one stage of the leather production process (deliming) is repurposed to treat wastewater from another stage (dyeing and fat liquoring). This concept of using waste to treat waste is in line with the principles of the circular economy, which aim to reduce waste generation, promote resource efficiency, and minimize environmental impacts (Saritha, *et al*., 2011). The reuse of deliming wastewater as a coagulant for the treatment of dyeing and fat liquor effluents is a promising innovation that can offer multiple benefits. Such as lowering the overall cost of wastewater treatment, promotes resource recovery, minimizes waste in the leather industry, and supports sustainable development goals by creating a closed-loop system with a reduced environmental footprint (Tiravanti, *et al*., 2009; Saritha, *et al*., 2011; Shaibur, *et al*., 2023; Rao, *et al*. 2024). Despite the potential advantages, there is limited data on its effectiveness in treating dyeing and fat liquor wastewater, particularly in reducing BOD, COD, TDS, turbidity, and conductivity (Sathya, *et al*., 2022; Ahmed, *et al*., 2011; Hansen, *et al*., 2021). These parameters are critical indicators of wastewater quality and are commonly used to assess the efficiency of treatment processes (Hansen, *et al*., 2021). BOD and COD provide insights into the organic load of the wastewater, with higher values indicating a greater demand for oxygen in biological treatment processes. TDS and conductivity indicate the dissolved inorganic salts and ions in the effluent, which can affect the salinity and overall quality of receiving water bodies. Turbidity measures the cloudiness or clarity of the water, which can impact light penetration and the aesthetic quality of water bodies (Sathya, *et al*., 2022; Ahmed, *et al*., 2011; Hansen, *et al*., 2021). This study aims to investigate the efficiency of deliming wastewater as a coagulant in treating dyeing and fat liquor effluents. The primary objective is to assess the reduction of key pollutants, including BOD, COD, TDS, turbidity, and conductivity, through batch studies of coagulation (using dyeing and fat liquoring wastewater). By exploring this novel approach, the research seeks to provide a sustainable solution for treating complex industrial wastewater, with potential implications for improving environmental outcomes and reducing the ecological footprint of tannery operations.

2. Method and Materials

2.1 Study Area

The study focuses on the Hazaribagh Tannery Industrial area, located in the southwestern part of Dhaka, Bangladesh, between latitudes 23°44´ to 23°45´ and longitudes 90°22.15´ to 90°21.85´

(Chowdhury, *et al*., 2013). We collected effluent samples from three tanneries: Samina, Ruma, and Chowdhury. These tanneries are well-known for producing various types of leather and exporting crust and finished leather to the U.S. and European markets.

2.2 Sample Collection

The study, conducted in 2022, focused on collecting deliming, dyeing, and fat-liquoring effluents from the outlets of three selected leather industries in the Hazaribagh leather processing zone, Dhaka, Bangladesh. We collected effluent samples from the discharge points of specific tanning operations. The collected samples were stored in polyethylene bottles at a controlled temperature of 4±1°C in the laboratory (Pearson, *et al*., 1987).

2.3 Treatment Process

Separate experiments were performed in 500 ml beakers to mix deliming, dyeing, and fat-liquoring effluents in various proportions. The mixing proportions included dye and delime at ratios of 1:1 (50:50 ml), 2:1 (100:50 ml), and 1:2 (50:100 ml), as well as delime and fat liquoring at ratios of 1:1 (50:50 ml), 2:1 (100:50 ml), and 1:2 (50:100 ml). The mixtures were allowed to settle at room temperature for 48 hours and then filtered using Whatman filter paper. The resulting filtrates were analyzed to evaluate the effectiveness of the treatment process for tannery effluents.

2.4 Tannery Effluent Characteristics and Effluent Analysis

The physical parameters of raw tannery effluents, including Biological Oxygen Demand over 5 days at 20°C (BOD_5), Chemical Oxygen Demand (COD), conductivity, total dissolved solids (TDS), turbidity, pH, and chromium concentration, were analyzed. BOD and COD were determined following the standard APAH method (APHA 2005). We measured turbidity with a Digital Direct Reading turbidity meter (Orbeco-Hellige), TDS, conductivity, and pH with a HACH meter, whereas chromium concentration using an Atomic Absorption Spectrophotometer (AAS-7000 SHIMADZU).

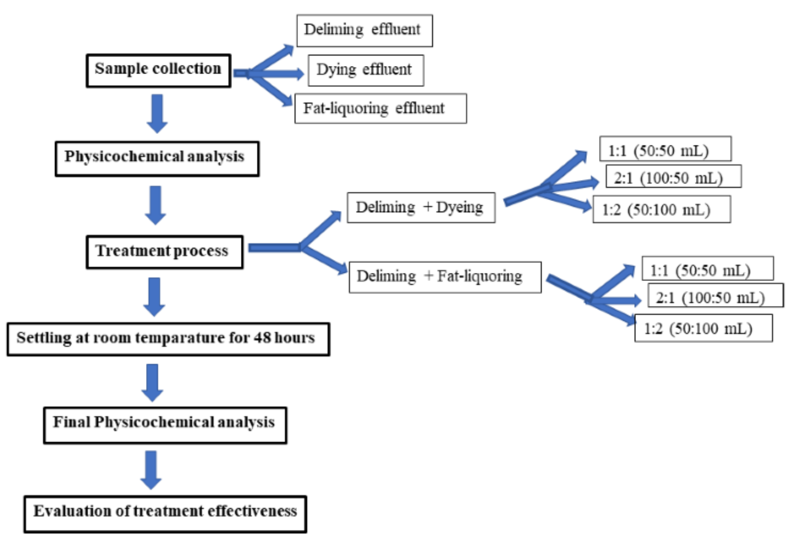

Figure 1: Methodology for tannery effluent collection, treatment, and analysis.

3. Result and Discussions

3.1 Characterization of Tannery Waste Water

Table 1: Characteristics of raw deliming and dyeing tannery effluent

Name of tannery	Operational Stage	BOD (mg/L)	COD (mg/L)	TDS (mg/L)	Turbidity (NTU)	Conductivity (µs/cm)	pH
Samina	Delime	2839	11030	45110	870	91020	8.8
	Dye	4550	14360	47710	950	95150	5.05
Ruma	Delime	2250	8875	39150	890	80100	9.1
	Dye	4156	13150	50100	990	101000	4.9
Chowdhury	Delime	2390	10156	49500	950	98150	9.0
	Dye	5500	17530	45150	910	91550	4.5
Standard limits (ISI-2000/ IWS-BDS) (ECR, 1997; GOB, 1997)		30/250	250/400	210	NA	NA	6-9

Table 2: Characteristics of raw deliming and fat liquoring tannery effluent

Name of tannery	Operational Stage	BOD (mg/L)	COD (mg/L)	TDS (mg/L)	Turbidity (NTU)	Conductivity (µs/cm)	pH
Samina	Delime	3015	11330	49155	980	98110	8.9
	Fat liquoring	5710	18155	50150	950	100110	5.1
Ruma	Delime	3000	12165	55219	964	112100	9.0
	Fat liquoring	57150	7755	50535	970	99950	5.5
Chowdhury	Delime	3259	13150	49380	921	98155	8.9
	Fat liquoring	6018	19923	51220	1040	102110	5.0
Standard limits (ISI-2000/ IWS-BDS) (ECR, 1997; GOB, 1997)		30/250	250/400	210	NA	NA	6-9

The analysis results of raw deliming and dyeing tannery effluent are shown in Table 1. The value of BOD, COD, turbidity, conductivity, and pH were found to be in the range of 5500 mg/L to 2250 mg/L, 17530 mg/L to 8875 mg/L, 50100 mg/L to 39150 mg/L, 990 NTU to 870 NTU, 101000 µs/cm to 80100 µs/cm and 9.1 to 4.5 respectively. On the other hand, the analysis results of raw deliming and fat liquoring tannery effluent are shown in Table 2. The value of BOD, COD, TDS, Turbidity, Conductivity and pH were found to be in the range of 6018 mg/L to 3000 mg/L, 19923 mg/L to 18155 mg/L, 55219 mg/L to 49155 mg/L, 1040 NTU to 921 NTU, 102110 µs/cm to 98110 µs/cm and 9.0 to 5.0 respectively. The analyzed results illustrated that BOD, COD, TDS, turbidity, and conductivity were much higher than those of the prescribed standard level.

The values were entirely unexpected and harmful to fish and aquatic environments. Deliming wastewater contains ammonium sulfate, dyeing wastewater contains different dyes, and fat liquoring wastewater contains natural and synthetic oils like sulfonated oils (Mattei, and Roddy, 1957; Pisarevsky, *et al*., 2005; Manvelova, *et al*., 2003; Ghasemi, *et al*., 2017). Ammonium sulfate can act as a coagulant for dyeing wastewater.

3.2 Effect of pH on Treatment of Effluent

The effect of pH on the removal of BOD, COD, TDS, turbidity, and conductivity of tannery effluent are shown in Table 3-7. For coagulation of dyeing and deliming wastewater, it can be seen that COD, BOD, TDS, Turbidity, and Conductivity removal are most effective at a pH range between 6.0 to 6.5 near to neutral pH. The Table also shows that an increase in the deliming dose is associated with an increase in the solution pH. On the other hand, increasing the dyeing dose is related to a decrease in the solution pH. The maximum removal was achieved at a proportion of dye 1:2 delime. Again, for coagulation of deliming and dyeing wastewater, it can be seen that COD, BOD, TDS, turbidity, and conductivity removal are also most effective at a pH range between 6.0 to 6.5 near to neutral pH. In this case, an increase in the deliming dose is associated with an increase in the solution pH. On the other hand, increasing the fat liquoring dose is related to a decrease in the solution pH (Prabhavathy, and De, 2010. Bresolin, *et al*., 2025; Bera, *et al*., 2025). The maximum removal was achieved at a proportion of delime 2:1 fat liquoring.

3.3 Reduction of Biological Oxygen Demand (BOD)

Table 3: Removal percentage of BOD

Proportion of effluent mixture	**Name of Tannery**								
	Samina			**Ruma**			**Chowdhury**		
	BOD after treatment (mg/L)	**Percentage of removal**	**pH**	**BOD after treatment (mg/L)**	**Percentage of removal**	**pH**	**BOD after treatment (mg/L)**	**Percentage of removal**	**pH**
Dye:Delime (1:1) 50ml:50ml	1757	76.22%	5.8	1440	77.55%	5.9	1850	76.55%	5.7
Delime: Fatliquoring (1:1) 50ml:50ml	1815	79.19%	5.7	1715	97.15%	5.8	1740	81.24%	5.7
Dye:Delime (1:2) 50ml:100ml	1550	79.02%	6.4	1417	77.88%	6.3	1805	77.12%	6.5
Delime: Fatliquoring (1:2) 50ml:100ml	2219	74.56%	5.3	2310	96.16%	5.3	2318	75.01%	5.2
Dye:Delime (2:1) 100ml:50ml	1810	75.50%	5.3	1860	70.56%	5.1	2150	72.56%	5.0
Delime: Fatliquoring (2:1) 100ml:50ml	1915	78.05%	6.8	1800	97.00%	6.5	1890	79.63%	6.4

Table 3 presents the impact of treatment on BOD removal efficiency. For dye-delime coagulation, the BOD concentration decreased from 79.02% to 70.96%. The optimum level of BOD removal was achieved using dye 1:2 delime proportion. The rate of BOD removal decreased if the dyeing wastewater was higher than the deliming wastewater in the solution (Dabagh, *et al*., 2025; Shakya, *et al*., 2025). On the contrary, for delime-fat liquor the effect of treatment on the removal of BOD concentration decreased by 97.15% to 74.56%. The optimum level of BOD removal was achieved using Delime1:1Fat liquoring proportion which is 97.15%. Comparable levels have also been documented in another study conducted by Barman et. al. (2017), where the authors claimed maximum removal efficiency (78%) of BOD5 was obtained for alum and ferric chloride combination at a 75 mg/L dose.

3.4 Removal of Chemical Oxygen Demand (COD)

Table 4: Removal percentage of COD

Proportion of effluent mixture	**Name of Tannery**								
	Samina			**Ruma**			**Chowdhury**		
	COD after treatment (mg/L)	**Percentage of removal**	**pH**	**COD after treatment (mg/L)**	**Percentage of removal**	**pH**	**COD after treatment (mg/L)**	**Percentage of removal**	**pH**
Dye:Delime (1:1) 50ml:50ml	5050	80.11%	5.8	3879	82.39%	5.9	4050	85.38%	5.7
Delime: Fatliquoring (1:1) 50ml:50ml	4012	86.39%	5.7	3818	80.83%	5.8	3815	88.46%	5.7
Dye:Delime (1:2) 50ml:100ml	4910	80.66%	6.4	3510	84.03%	6.3	4110	85.15%	6.5
Delime: Fatliquoring (1:2) 50ml:100ml	4558	84.54%	5.3	4954	75.13%	5.3	5014	84.84%	5.2
Dye:Delime (2:1) 100ml:50ml	5508	78.3%	5.3	4280	80.57%	5.1	4815	82.62%	5.0
Delime: Fatliquoring (2:1) 100ml:50ml	3915	86.72%	6.8	9050	54.57%	6.5	4157	87.43%	6.4

Table 4 presents the impact of treatment on BOD removal efficiency. After adding deliming wastewater to dye at a proportion of dye 1:1 delime (50:50 ml), dye 2:1 delime (100:50 ml), dye 1:2 delime (50:100 ml), the COD concentration decreased by 78.31% to 85.38%. The result shows that at a ratio of 1:2, delime gives the highest removal percentage of COD compared to other proportions. On the contrary, for delime-fat liquor coagulation after adding delime waste water to fat liquor wastewater at a proportion of delime 1:1 fat liquor (50:50 ml), delime 2:1 fat liquor (100:50 ml), delime 1:2 fat liquor (50:100 ml); the COD concentration decreased by 54.57% to 88.46%. The highest removal percentage was achieved at a ratio delime 1:1 fat liquor proportion. However, our present study is supported by Haydar & Aziz (2009), who reported the highest removal of total chemical oxygen demand (TCOD) using coagulation–flocculation–sedimentation with alum and cationic and anionic polymers. In another study, Barman *et al*. (2017) reported 76% removal of total COD using low-cost coagulants via simple coagulation and filtration.

3.5 Reduction of Different Physicochemical Parameters

Table 5: Removal percentage of TDS

Proportion of effluent mixture	Samina: TDS after treatment (mg/L)	Samina: Percentage of removal	Samina: pH	Ruma: TDS after treatment (mg/L)	Ruma: Percentage of removal	Ruma: pH	Chowdhury: TDS after treatment (mg/L)	Chowdhury: Percentage of removal	Chowdhury: pH
Dye:Delime (1:1) 50ml:50ml	17780	80.08%	5.9	17700	80.93%	5.8	19110	79.81%	5.7
Delime: Fatliquoring (1:1) 50ml:50ml	17715	82.16%	5.7	16654	84.25%	5.8	16480	83.62%	5.7
Dye:Delime (1:2) 50ml:100ml	15150	83.03%	6.3	18150	80.45%	6.4	20110	78.752%	6.5
Delime: Fatliquoring (1:2) 50ml:100ml	20220	79.64%	5.3	20230	80.87%	5.3	20215	79.91%	5.2
Dye:Delime (2:1) 100ml:50ml	19110	78.59%	5.1	17900	80.6%	5.3	22150	76.60%	5.0
Delime: Fatliquoring (2:1) 100ml:50ml	18130	81.74%	6.8	18110	82.88%	6.5	18130	81.98%	6.4

Table 6: Removal percentage of Turbidity

Proportion of effluent mixture	Samina: Turbidity after treatment (NTU)	Samina: Percentage of removal	Samina: pH	Ruma: Turbidity after treatment (NTU)	Ruma: Percentage of removal	Ruma: pH	Chowdhury: Turbidity after treatment (NTU)	Chowdhury: Percentage of removal	Chowdhury: pH
Dye:Delime (1:1) 50ml:50ml	169	91.01%	5.9	263	85.55%	5.8	180	90.32%	5.7
Delime: Fatliquoring (1:1) 50ml:50ml	121	93.73%	5.7	13	92.86%	5.8	125	93.63%	5.7
Dye:Delime (1:2) 50ml:100ml	160	91.49%	6.3	180	90.11%	6.4	204	89.03%	6.5
Delime: Fatliquoring (1:2) 50ml:100ml	184	90.47%	5.3	19	90.12%	5.3	182	90.72%	5.2

Dye:Delime (2:1) 100ml:50ml	191	89.84%	5.1	221	87.66%	5.3	221	88.19%	5.0
Delime: Fatliquoring (2:1) 100ml:50ml	143	92.59%	6.8	163	91.57%	6.5	146	92.55%	6.4

Table 7: Removal percentage of Conductivity

Proportion of effluent mixture	**Name of Tannery**								
	Samina			**Ruma**			**Chowdhury**		
	Conductivity after treatment (µs/cm)	**Percentage of removal**	**pH**	**Conductivity after treatment (µs/cm)**	**Percentage of removal**	**pH**	**Conductivity after treatment (µs/cm)**	**Percentage of removal**	**pH**
Dye:Delime (1:1) 50ml:50ml	35500	80.40%	5.9	34550	81.44%	5.8	38210	79.86%	5.7
Delime: Fatliquoring (1:1) 50ml:50ml	34150	82.77%	5.7	33150	84.37%	5.8	32250	83.89%	5.7
Dye:Delime (1:2) 50ml:100ml	29850	83.52%	6.3	35110	81.14%	6.4	40010	78.91%	6.5
Delime: Fatliquoring (1:2) 50ml:100ml	40884	79.37%	5.3	40448	80.92%	5.3	40520	79.77%	5.2
Dye:Delime (2:1) 100ml:50ml	38240	78.88%	5.1	34150	81.66%	5.3	42990	77.34%	5.0
Delime: Fatliquoring (2:1) 100ml:50ml	35955	81.83%	6.8	37100	82.50%	6.5	30250	84.89%	6.4

Table 5-7 shows the influence of dye-delime coagulation on removing TDS, turbidity and conductivity from waste water. After the addition of deliming wastewater with dyeing effluent at a proportion of dye 1:1 delime (50:50 ml), dye 2:1 delime (100:50 ml), dye 1:2 delime (50:100 ml), the TDS, turbidity and conductivity concentration decreased by 76.60% to 83.03%, 87.86% to 91.49% and 77.34% to 83.52% respectively. The maximum removal percentage of TDS, turbidity, and conductivity was achieved at a proportion of dye 1; 2 delime. Ammonium sulfate from the deliming solution reacts with dye from the dyeing solution and precipitates as a complexion. On the other hand, the influence of delime-fat liquor coagulation on the removal of TDS, turbidity, and conductivity from wastewater showed different scenarios. After the addition of deliming wastewater with fat liquoring effluent at a proportion of delime 1:1 fat liquoring(50:50 ml), delime 2:1 fat liquoring (100:50 ml), delime 1:2 fat liquoring (50:100 ml), the TDS, turbidity, and conductivity concentration decreased by 79.64% to 84.25%, 90.12% to 93.73% and 79.77% to 84.89% respectively. The optimum level of removal for TDS, turbidity and conductivity was achieved at a proportion of delime 1:1 fat liquoring. Ammonium sulfate from deliming solution reacts with sulfonated oil from fat liquoring solution and precipitates as complexion (Chowdhury, *et al*., 2013; Dabagh, *et al*., 2025). At the national scale, previous studies from Bangladesh have reported substantially similar removal efficiencies for TDS, turbidity, and conductivity: 87%, 94%, and 81%, respectively, obtained with the combination of alum and ferric chloride (Barman *et al*. 2017). Whereas relatively higher levels of removal efficiency for TDS (81%), turbidity (96%), and conductivity (87%) were reported by Hashem *et al*. (2016) using oxidation-coagulation-filtration techniques.

4. Conclusion

Tannery effluents from the Hazaribagh tannery industrial area pose significant environmental concerns due to BOD, COD, TDS, turbidity, and conductivity levels exceeding standard recommendations. In this experiment, deliming, dyeing, and fat-liquoring effluents at ratios of 1:1, 2:1, and 1:2 were tested to evaluate their coagulation efficacy in reducing various physicochemical characteristics. However, analysis reports suggest that the most effective removal of pollutants occurs within a pH range of 6.0 to 6.5, with optimized effluent mixtures. The optimum levels of BOD (97.15%), COD (88.46%), TDS (83.62%), turbidity (93.63%), and conductivity (83.89%) removal were achieved using a 1:1 delime fat liquoring proportion. Thus, we may conclude that there is an urgent need to implement pH-adjusted coagulation methods to assist in developing in-house treatment systems before discharge, and implement cost-effective effluent treatment strategies to mitigate the environmental impact of tannery operations.

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