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PERFORMANCE OPTIMIZATION OF SYNTHETIC COAGULANTS IN LAUNDRY WASTEWATER PURIFICATION

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Abstract: Domestic laundry wastewater is becoming a major concern due to the advent of automatic washing machines, which generate large volumes of greywater. Wastewater treatment is a big challenge due to increase in activities related to the generation of wastewater. Due to increase in the population growth rate, water scarcity is becoming a major problem. Wastewater should be treated before discharging into water bodies because it can lead to harmful effects on aquatic life and the environment. The main objectives of this study are to evaluate the performance of conventional synthetic coagulants for laundry wastewater treatment. In this study, four synthetic coagulants were used for the coagulation-flocculation process, which include alum, polyaluminium chloride, calcium chloride, and ammonium chloride. The sample was collected from an automatic washing machine. A jar test experiment was conducted, and four different dosages (1.5, 2.5, 3.5 and 4.5g/100ml) of each coagulant were taken. Physicochemical parameters: pH, electrical conductivity (EC), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), and turbidity were measured before and after treatment. Results show that polyaluminium chloride shows the highest turbidity removal efficiency of 97% at a dose of 4,5g/100ml and pH level of 7, while alum shows removal efficiency (96%) at the dose of 4.5g/100ml, a pH level sustainable to 5.7. Calcium chloride shows 56%, and ammonium chloride shows only 48% turbidity removal. PAC is also best at removing suspended particles (from 64mg/l to 6mg/l) and COD from 178mg/l to 149mg/l, marginally meeting Pakistan Environmental Quality Standards. Alum shows a reduction of TSS from 67mg/l, 8mg/l, but generates acidic effluents. Calcium and ammonium chloride show limited removal of pollutants from wastewater; both of these coagulants have weak coagulation properties. TDS values of all synthetic coagulants increased with increasing dosage due to chemical dissociation of these salts into water. The results show that among all of the synthetic coagulants, PAC is the best coagulant for the treatment of laundry wastewater. Ammonium and calcium chloride are not good options for the laundry wastewater treatment.

Keywords: Synthetic coagulants, laundry wastewater, physicochemical parameters, turbidity, coagulation-flocculation.

Introduction

Water is an essential resource for vegetation, industrial growth, human existence, and ecological survival. Water scarcity has grown to be a significant problem as a result of population growth, (Shemer *et al.*, 2023). Just 1% of water is suitable for human use. Wastewater generation has also grown, which badly affects the environment. Wastewater discharge into natural water bodies has the potential to seriously harm the environment (Mishra, 2023). According to a survey, about 800 million people worldwide reside in regions, where water scarcity is an issue. Reducing consumption and concentrating on water reuse are the primary concerns due to scarcity of fresh water (Musie and Gonfa, 2023).

Laundry wastewater is a major contributor to grey water that is generated by washing machines, which contains high levels of phosphate, detergents, suspended particles, and organic matter (Awasthi *et al.*, 2024). If laundry wastewater is discharged into water bodies without treatment, its effluents lead to eutrophication, which is harmful to aquatic life and the environment. Due to changes the quality of water. Due to the high concentration of detergents in laundry wastewater, the majority of laundry effluents are naturally alkaline, but pH changes due to the addition of coagulants in wastewater for the treatment process.

Many methods are used for wastewater treatment, but coagulation is the most preferred due to its simplicity and cost-effectiveness (Ali *et al.*, 2025). Coagulation-flocculation plays an important role in removing suspended particles, organic matter, and pollutants from complex wastewater. Polyaluminum chloride and alum are the most preferable synthetic coagulants for the treatment, but some drawbacks of synthetic coagulants are noticed, such as they generate a large volume of toxic sludge that is non-biodegradable and changes the pH value. The production of sludge depends on the type of coagulants and the nature of the wastewater (Koul *et al.*, 2022).

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Reclamation and reuse of decentralized home wastewater have become an ecological imperative due to rapid urbanization and worsening worldwide water scarcity (He *et al.*, 2021). Blackwater (toilet effluent) and greywater (discharges from showers, sinks, and laundry facilities) are the two main categories of domestic wastewater (Umapathy *et al.*, 2024). The industrial laundry processes produce huge amounts of wastewater with a highly complicated structure of organo-mineral contaminants.

These effluents are usually characterized by high levels of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), and Total Suspended Solids (TSS) (Chockalingam *et al.*, 2019). The main issue in treating this stream is the presence of high levels of anionic surfactants, which may reach several grams per liter, and new contaminants like microplastics and heavy metals also emerging. These materials not only add to the organic load but may also negatively impact the subsequent biological treatment processes by competing with oxygen transfer and the settling out of particles (Wang *et al.*, 2016).

Alum ($Al_2(SO_4)_3 \cdot 18H_2O$) is the most often used coagulant in water and wastewater treatment due to its inexpensive cost, widespread availability, and proven performance in various water quality circumstances. Upon dissolution, alum undergoes a series of hydrolysis reactions, resulting in amorphous $Al(OH)_3$ flocs with a large surface area capable of adsorbing suspended particles, colloids, and dissolved organic matter (Yan *et al.*, 2007); (Sahu and Chaudhari, 2013) (Bratby, 2006).

According to Pakistan's National Environmental Quality Standards (NEQS), home and industrial wastewater discharge limitations are set at pH 6–10, BOD ≤80 mg/L, COD ≤150 mg/L, and TSS ≤200 mg/L. It is necessary to systematically assess coagulant type, dosage, and pH to meet these guidelines for home laundry effluent using synthetic coagulation.

There are still a few systematic comparative studies that particularly, address synthetic coagulant performance for residential laundry effluent in developing-country contexts, despite the widespread creation of laundry wastewater and its established environmental significance (Ilyas *et al.*, 2019).

This study will examine the gap through the jar test method of four synthetic coagulants for domestic laundry wastewater treatment. The main objectives of this study are to identify which synthetic coagulants are best and show high turbidity removal efficiency, identify the optimal dosage and pH condition for each coagulant, and determine the BOD, COD, TSS, TDS, pH, and turbidity level before and after treatment.

Materials and Methods

Research Design

This experimental work evaluates the performance of synthetic coagulants in treating laundry wastewater. The main focus is to remove all the suspended particles, organic matter, and pollutants from wastewater. In this experimental work, the main aim is to determine the dosage at which coagulants show the best removal efficiency of turbidity, TSS, and COD.

Chemical Coagulants

Four synthetic coagulants were taken for domestic laundry wastewater treatment. Alum is the most common coagulant used for the treatment of wastewater, including laundry wastewater. It is effective in reducing organic matter and turbidity from wastewater. Alum is cost-effective, and it decreases the pH value, which requires attention because it produces acidic effluents that are toxic to aquatic life.

Polyaluminum chloride is a pre-polymerized coagulant, and it is one of the most popular coagulants used for the treatment of laundry wastewater due to its higher efficiency in removing turbidity. It is very effective in removing suspended particles and pollutants from wastewater.

Its performance is outstanding when it comes to water quality, because it clears water very efficiently. Calcium and ammonium chloride show weak coagulation properties as compared to alum and Polyaluminium chloride. Both show the least removal efficiency of TSS and COD.

Sample Preparation and Treatment

Before starting experimental work, the glass jar is washed properly to remove any contamination and then dried. Then, 2 L of sample laundry wastewater is added to the beaker and mixed properly with the help of a magnetic stirrer.

Initial readings of the sample are taken, which are pH, EC, TSS, TDS, BOD, COD, and turbidity, before treatment.

Table 1. The different dosages of synthetic coagulants

Category	Coagulant	Dosages (g/l)	Volume of sample (ml)
Synthetic	Alum	1.5, 2.5, 3.5, 4.5	100
Synthetic	Polyaluminium chloride	1.5, 2.5, 3.5, 4.5	100
Synthetic	Calcium chloride	1.5, 2.5, 3.5, 4.5	100
Synthetic	Ammonium chloride	1.5, 2.5, 3.5, 4.5	100

Table 2. Showing the pH, EC, TSS, TDS, BOD, COD, and turbidity of different doses of Alum

Dosage (g/L)	pH	EC (µS/cm)	TSS (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Turbidity (NTU)
1.5	6.8	2095	67	1340	88	220	95
2.5	6.7	2100	48	1344	80	200	68
3.5	5.9	2250	25	1440	72	180	35
4.5	5.7	2400	8	1536	69	173	11

Sixteen jars were taken, and 100ml of water was added to each jar.

Then add different dosages (1.5, 2.5, 4.5 and 4.5g/l) of each coagulant is added into 100ml of water. After this, the sample is mixed rapidly and then slowly. After 3.4 days, the filtration step is performed. The supernatant is collected by filtration using Whatman filter paper, and after this, the physicochemical parameters of each sample are measured.

Data Analysis

The percentage removal efficiency of each parameter before and after treatment using standard removal efficiency formulas was calculated. Graphical representations, including bar charts and line graphs, were developed to visually compare the efficiency of each coagulant with different dosages.

These results help to determine the most effective coagulant for treating laundry wastewater.

Removal Efficiency Calculation

Percentage removal efficiency (E%) for each parameter was calculated as:

$$\text{Removal Efficiency (\%)} = \frac{C_i - C_f}{C_i} \times 100$$

C_i= Initial concentration of the pollutant (e.g., COD, BOD, or TDS before treatment in mg/L).

C_f=Final concentration of the pollutant (after treatment/ filtration in mg/L).

Results and Discussion

Effect of Alum on Physicochemical Parameters

The laundry wastewater is treated using alum as a coagulant. Different doses of alum were used. By increasing the dosage of coagulant, the pH value declines from 6.8 at a dose of 1.5g/l to 5.7 at a dose of 4.5g/l. Alum shows an acidic nature at higher dosages. TSS value reduced from 67mg/l to 8mg/l. Alum shows high TSS removal efficiency at a dosage of 4.5g/l. Alum is a very effective coagulant in removing suspended particles from wastewater. TDS increased from 1,340 to 1,536 mg/L at the highest dose, reflecting ionic dissolution from aluminium sulphate.

By increasing the dosage of alum, BOD and COD values will decrease, which shows that alum is very effective in removing organic matter and pollutants from wastewater. Turbidity removal was highly effective at a dosage of 4.5g, and the removal efficiency was 96%. By increasing the amount of alum in wastewater, the turbidity removal efficiency increased from 64 to 96%.

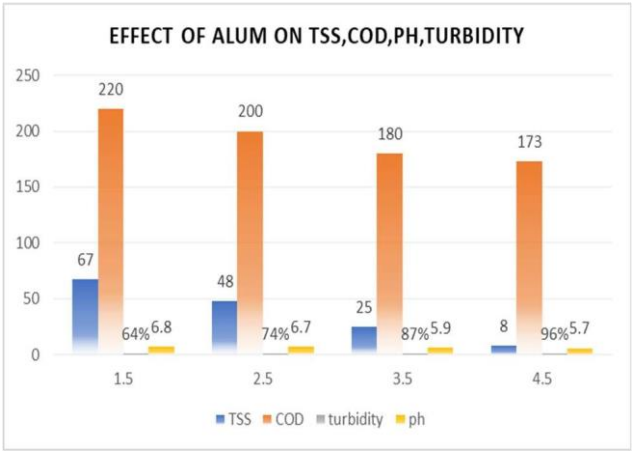


Fig. 1 Comparison of physicochemical parameters of Alum.

Effect of Polyaluminium Chloride on Physicochemical Parameters

PAC is the most popular coagulant used in laundry wastewater treatment. It shows highest removal efficiency of 97% at a dose of 4.5g/l. The pH declines from 7.4 to 7, showing its pre-hydrolysis pH buffering capacity. The TSS value is reduced from 46mg/l to 6mg/l. It indicates that PAC is highly effective in settling suspended particles. TDS is increased because coagulants dissociate soluble ions into the water. BOD, COD values decline, so its show PAC is effective in removing organic matter from the wastewater it indicates that PAC is highly effective in settling suspended particles. TDS is increased because coagulants dissociate soluble ions into the water. BOD, COD values decline, so its show PAC is effective in removing organic matter from the wastewater.

Effect of Calcium Chloride on Physicochemical Parameters

This coagulant maintains the basic effluent pH of 7.8 to 8.0 across all dosages. TSS value decreased modestly from 113

mg/l to 84 mg/l. The efficiency of calcium chloride in solid removal was limited. This coagulant is not more effective than alum and PAC. It is less effective for removing organic pollutants from wastewater. BOD declined from 96 to 82 mg/L and COD from 240 to 206 mg/L, and both values exceed NEQS discharge limits. The removal efficiency was only 56% at the dose of 4.5g. It has weaker coagulation properties, so its removal efficiency was poor.

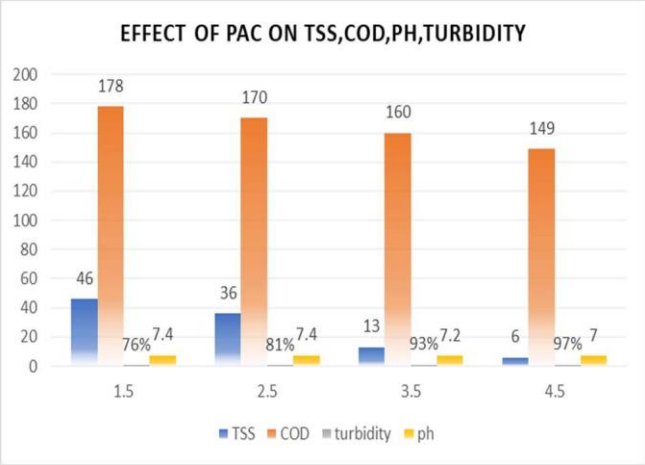


Fig. 2 Comparison of physicochemical parameters of PAC.

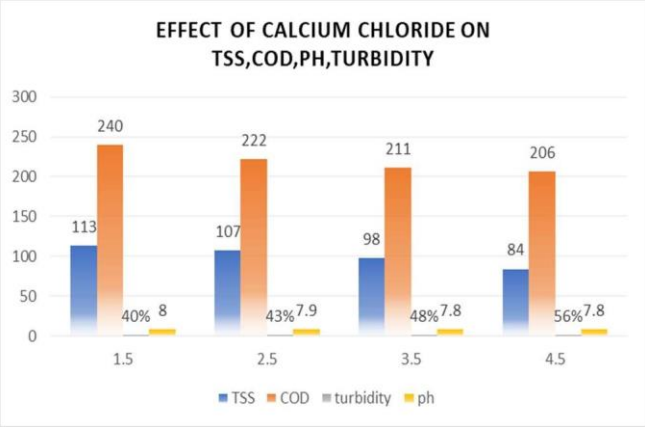


Fig. 3 Comparison of physicochemical parameters of calcium chloride.

Effect of Ammonium Chloride on Physicochemical Parameters

By increasing the dosage of ammonium chloride from 1.5g to 2.5g, the pH value slightly decreased from 8.2 to 8.0. Ammonium chloride is basically an acidic salt, but its pH has an alkaline nature because laundry wastewater contains detergents, which act as a buffer. Reduction occurs in TSS from 154mg/l to 98mg/l. As the dose increased, BOD values dropped from 146mg/l to 116mg/l, while COD values decreased from 365mg/l to 290mg/l. These values far exceed the NEQ Standards. Turbidity removal efficiency was only 48% at the dose of 4.5g/l. It shows less removal efficiency of all physicochemical parameters among all the coagulants.

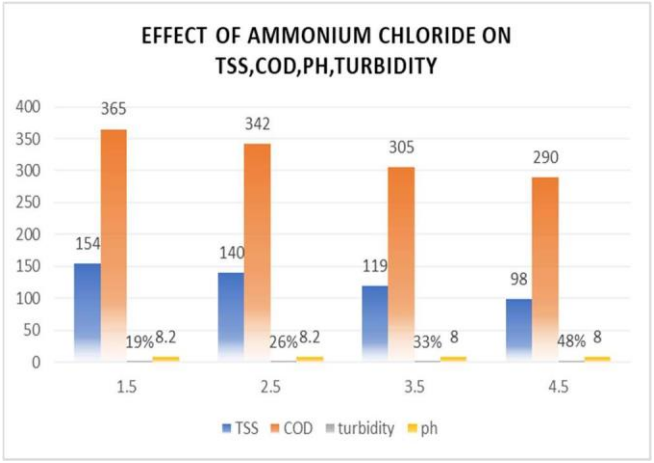


Fig. 4 Comparison of physicochemical parameters of ammonium chloride.

Conclusion

The laundry wastewater should be treated before discharge because the contaminants present in laundry wastewater are toxic to aquatic and human life. The treated laundry wastewater can be used in agricultural activities, such as for irrigation purposes. It can also be used for car washing, toilet flushing, and watering of plants.

References

Ali S.K., Abdou M.M., Emara M.M., Farag R.S. and Mubarak M.F. (2025). Eco-friendly solutions: A comprehensive review of natural coagulants for sustainable water treatment. *Environ. Geochem. Health*, **47**(12): 535.

Awasthi A., Gandhi K. and Rayalu S. (2024). Greywater treatment technologies: A comprehensive review. *Int. J. Environ. Sci. Technol.*, **21**(1): 1053–1082.

Chockalingam N., Banerjee S. and Muruhan S. (2019). Characterization of physicochemical parameters of textile effluents and their impacts on the environment. *Environ. Nat. Resour. J.*, **17**(2): 41–53.

He C., Liu Z., Wu J., Pan X., Fang Z., Li J. and Bryan B.A. (2021). Future global urban water scarcity and potential solutions. *Nat. Commun.*, **12**(1): 4667.

Ilyas M., Ahmad W., Khan H., Yousaf S., Yasir M. and Khan A. (2019). Environmental and health impacts of industrial wastewater effluents in Pakistan: A review. *Rev. Environ. Health*, **34**(2): 171–186.

Koul B., Bhat N., Abubakar M., Mishra M., Arukha A.P. and Yadav D. (2022). Application of natural coagulants in water treatment: A sustainable alternative to chemicals. *Water*, **14**(22): 3751.

Mishra R.K. (2023). Fresh water availability and its global challenge. *Br. J. Multidiscip. Adv. Stud.*, **4**(3): 1–78.

Musie W. and Gonfa G. (2023). Fresh water resource, scarcity, water salinity challenges and possible remedies: A review. *Heliyon*, **9**(8): e18685.

Sahu O. and Chaudhari P. (2013). Review on chemical treatment of industrial waste water. *J. Appl. Sci. Environ. Manage.*, **17**(2): 241–257.

Shemer H., Wald S. and Semiat R. (2023). Challenges and solutions for global water scarcity. *Membranes*, **13**(6): 612.

Umapathy S., Rajamanivannan H.B., Solaiappan V. and Swaminathan S. (2024). Towards sustainable homes: Exploring point-of-use treatment for laundry water recycling. *Water Air Soil Pollut.*, **235**(11): 712.

Wang Z., Zhang L., Zhao J. and Xing B. (2016). Environmental processes and toxicity of metallic nanoparticles in aquatic systems as affected by natural organic matter. *Environ. Sci.: Nano*, **3**(2): 240–255.



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