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# Performance Analysis of Poly Aluminium Chloride (PAC) in Turbidity, COD, and Microbial Load Reduction from Domestic Washing Machine Effluent and Urban Lake Water

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***Abstract: This study evaluates Poly Aluminium Chloride (PAC) as a coagulant for improving water quality by removing turbidity, chemical oxygen demand (COD), and microbial contaminants. Samples were collected from domestic washing machine effluent and an urban lake in Mysuru, Karnataka. Initial laboratory tests involved creating controlled turbidity levels using Bentonite clay to evaluate the effectiveness of PAC at different concentrations, followed by application to Domestic Washing Machine (DWM) Effluent and Urban Lake (UL) water. PAC achieved substantial reductions in turbidity, COD, and microbial load even at low dosages, producing compact sludge. The results confirm PAC as an efficient, sustainable coagulant suitable for urban and semi-urban water treatment applications in India.***
***Keywords: Domestic Washing Machine (DWM) Effluent, Urban Lake (UL) water, Poly Aluminium Chloride (PAC), Bentonite clay, Turbidity Removal, Chemical Oxygen Demand (COD), Microbial Contamination, Water Treatment.***

## I. INTRODUCTION

Water is a vital natural resource essential for sustaining life, agriculture, industry, and ecological balance, yet rapid urbanization and industrial growth have increased demand while deteriorating water quality. In most of the Urban area, lakes are act as freshwater resources and provide the numerous ecosystem services. But this situation was changed in 21st century, due to rapid urbanization, industrialization, Infrastructures development of cities, high population growth, water intensive life style, migration from rural to urban are increasing more pressure on freshwater resources and after utilization of water, tons of waste water dispose into water bodies, which is very close to urban areas especially in Urban lakes. Freshwater bodies are the major recipients for domestic wastewater and industrial effluents *(Bhat and Qayoom, 2021)*. Inadequate treatment infrastructure often results in poor-quality water characterized by turbidity, elevated chemical oxygen demand (COD), and microbial contamination [1]. Among emerging wastewater streams, domestic laundry effluents are of particular concern, as washing machines account for 15–40% of household water use and discharge 13–22 L of greywater per capita daily [6]. This effluent, enriched with detergents, surfactants, oils, and suspended solids, contributes significantly to organic pollution and microbial contamination if discharged untreated [3][4][6]. Turbidity, caused by negatively charged colloids such as clay, silt, organic matter, and microbes, is a key barrier to water quality improvement and is typically addressed through coagulation–flocculation [1]. Aluminium sulfate (alum) remains the most widely used coagulant due to its affordability and effectiveness, but its limitations include excessive sludge generation, pH reduction, dependence on chemical adjustment, and concerns over residual aluminium in treated water [7] [13]. As an alternative, Poly Aluminium Chloride (PAC), a pre-polymerized aluminium coagulant, offers several advantages: it contains highly charged polymeric species such as the $Al_{13}$ Keggin ion, is effective across wider pH and temperature ranges, forms compact and rapid-settling flocs, requires lower dosages, and produces less sludge, thereby reducing operational costs [7] [9] [10]. International studies in countries such as Malaysia, Greece, and Spain have confirmed PAC's superior performance in removing turbidity and COD compared to alum [1] [4] [9], but its adoption in India remains limited. Despite increasing interest, relatively few studies have evaluated PAC for treating complex wastewaters such as domestic laundry effluents or surface water bodies impacted by urban pollution. This study addresses that gap by assessing PAC's effectiveness in reducing turbidity, COD, and microbial loads in laundry effluent and urban lake water, thereby contributing practical insights into its applicability for sustainable water treatment.

## II. STUDY OBJECTIVE

1) To evaluate the efficiency of PAC in removing Turbidity, COD, and Microbial contaminants.
2) To assess the influence of pH and coagulant dosage on the treatment process
3) To identify optimal operational parameters for the effective application of PAC in practical water treatment scenarios.

## III. LITERATURE REVIEW

A. *Aina Asyura Azhar, Nuryazmeen Farhan Haron & Herda Balqis Ismail* conducted a comparative analysis of PAC and alum at the Sultan Iskandar Water Treatment Plant, Johor. PAC demonstrated slightly higher turbidity removal (83.74%) than alum, with lower residual aluminium and dosage requirements, making it a more efficient and cost-effective coagulant for large-scale treatment.
B. *Benis et al. (2021)* treated laundry wastewater through biological and physicochemical processes. Following microbial adaptation, 91% COD removal was achieved. Post-treatment with UV/O and membranes ensured full pollutant removal. This integrated system proved technically efficient and economically feasible for reuse, with a treatment cost of €0.65/m³.
C. *Moharir et al.* investigated industrial laundry wastewater treatment involving coagulation, ultrafiltration, ozonation, and more. With average daily discharge at 400 m³, key parameters such as COD, BOD, pH, and turbidity were evaluated. A multi-treatment approach was deemed essential for effective pollution reduction and water reuse compliance.
D. *Shaikh & Ahammed (2024)* analyzed greywater from laundry processes, noting high COD and surfactant loads. Treatment methods like coagulation, dissolved air flotation, ozonation, ultrafiltration, and adsorption were tested. Among these, advanced membrane processes showed high efficacy in pollutant reduction, supporting the feasibility of laundry greywater reuse.
E. *Malhotra, S.* reviewed PAC as a substitute for alum, highlighting issues of sludge volume and health concerns such as Alzheimer's due to alum residuals. PAC offered faster flocculation, denser sludge, and greater turbidity removal, especially in medium to high turbidity waters, making it a more suitable coagulant.
F. *Mbaeze, Agbazue & Orjioke* compared alum and ferrous sulphate for water treatment. While alum was superior for turbidity, TSS, and chloride removal, ferrous sulphate showed better COD, DO, and phosphate reduction. The study emphasized the need for coagulant selection based on specific treatment objectives and water characteristics.
G. *Zouboulis, Traskas & Samaras (2008),* in a full-scale plant study, found PAC more effective than alum in reducing turbidity and residual aluminium at lower dosages. It also extended filter life and performed well in both conventional and direct filtration setups, supporting PAC's use for operational and cost efficiency.
H. *Van Benschoten & Edzwald (1990)* investigated the hydrolytic reactions of alum and PAC. Alum showed no polymer formation, while PAC retained its structure even under acidic conditions. PAC exhibited better performance in cold water, suggesting its hydrolysis stability leads to enhanced treatment consistency and efficiency.
I. *Kumar & Balasundaram* evaluated PAC and alum at varying turbidity levels. PAC needed lower dosages and produced less sludge. Real sludge samples from a plant using river water were tested for brick-making. PAC, despite higher cost, was found more efficient and environmentally favourable due to better sludge handling.
J. *CPCB (Status of Water Treatment Plants in India)* highlighted India's water demand surge amid resource constraints and urbanization. Raw water variability complicates treatment. The report emphasized optimizing chemical use, minimizing sludge, and enhancing operational practices to improve potable water output and reduce treatment waste.
K. *Krishnananda Prabhu (2025)* discussed household water efficiency. Washing machines use up to 200 L per cycle, stressing the need for waste reduction. Rather than restricting use, efficiency strategies aim to maintain comfort while conserving water and energy. The proposed household practice promotes sustainability with minimal lifestyle disruption.
L. *Riva Ismawati et al. (2022)* evaluated PAC for tofu wastewater treatment. At 75 mg/L dosage, PAC significantly reduced BOD, COD, and TSS, confirming its efficacy in managing high-strength organic effluent. The findings promote PAC use as a simple yet effective solution before wastewater discharge into aquatic systems.

## IV. MATERIALS AND METHODS

### A. *Materials*

To conduct the experimental study on coagulation performance, the following materials were utilized:

1) *Bentonite Clay:* Used as a turbidity-inducing agent to simulate controlled turbidity levels in water, enabling a systematic evaluation of coagulant effectiveness (Fig.1).

2) *Poly Aluminium Chloride (PAC):* Industrial grade PAC employed as the primary coagulant for treating both synthetic and real water samples (Fig.2).
3) *Washing Machine Wastewater:* Collected from domestic source to represent greywater with high organic and surfactant load (Fig.3).
4) *Freshwater Samples from Urban Lake:* Water sample was collected from selected urban lake in Mysuru to assess PAC's performance under natural environmental conditions (Fig.4).

Fig.1. Bentonite Clay

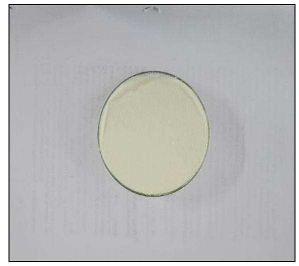


Fig.2. Poly Aluminium Chloride


Fig.3. Washing Machine Waste water sample

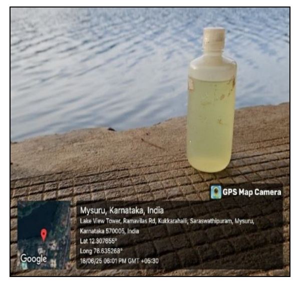



Fig.4. Kukkaralli lake Fresh water sample

B. *Methods*
1) *Collection of Washing Machine water:* To simulate domestic laundry wastewater, a standard Top-load washing machine was operated using around 50 litres of freshwater mixed with 100 grams of commercial surfactant detergent. A load of eight used cotton garments was washed under typical household washing conditions for approximately 30 minutes. Upon completion of the wash cycle, the resulting wastewater was collected directly from the machine's outlet for subsequent physicochemical and microbial analysis.
2) *Collection of fresh water sample:* Water sample was collected from 1 Urban Lake located within the city limits of Mysuru. The sampling was carried out from surface water near the shoreline using clean, sterilized containers. The collected samples were stored in airtight polyethylene bottles, labelled appropriately, and transported immediately to the laboratory for physicochemical and microbial analysis. All necessary precautions were taken to minimize contamination during sampling, handling, and storage.
3) *Jar test method:* Coagulation-flocculation is the most often used process in sewage treatment plants because of its efficacy. The investigation was conducted utilizing the jar test apparatus to assess and optimise coagulation-flocculation. Each of the six-bladed stirrers in the jar test apparatus rotates at a different speed, ranging from 0 to 150 rpm. The input variables were the coagulant dose of Poly Aluminium Chloride (PAC) dosage (0.2–1.20 g/L) for treating 10,20,30 & 40 NTU of pH ranging (7.04-7.62) Turbid water induced by Bentonite clay., (PAC) dosage (0.25–1.50 g/L) for treating the Domestic Washing Machine (DWM) Effluent of pH 10.5, and (PAC) dosage (0.025-0.055 g/L) for treating Fresh water from lake of pH (8.52). However, the dependent variables for coagulation-flocculation performance were *pH*, *turbidity*, *Sludge*, *bacterial/Microbial CFU*, and *COD*. By adding 1 N $H_2SO_4$ or 1 N NaOH solution, the pH of the wastewater in the sample was brought to the intended pH ranges between the number and altered pH levels. The experiment is conducted in three stages: rapid mixing for One minute at 120 rpm, gentle mixing for 20 minutes at 20 rpm, and finally settling for a 30 min range at 30±2ºC. The volume of sludge (dense floc) was measured after the settling period, and the supernatant was taken out and put in the flask for further examination.

4) *Determinations of Turbidity:* Turbidity is a physical property of fluids that translates into their reduced optical transparency, cloudiness, or haziness due to the presence of suspended material that blocks the transmission of light [11]. Nephelometric turbidity meters are used to measure turbidity. Before measuring the turbidity, the device was turned on and given it ten to fifteen minutes to warm up. After filling the glass cell with distilled water, it was placed within the cell holder and the lid was shut. A zero-adjusting knob can be used to set the panel meter to zero for calibration. After calibration, the distilled water cell was removed, the sample cell containing the test water was placed in the holder, and the lid was closed for turbidity measurement. Further the water sample solutions measurements were obtained from the turbidity meter and noted.
5) *Determinations of pH:* A digital pH meter is used to find the solution's pH. Electrode in put into two standard buffer solutions, each containing 100 millilitres of pH 4 and 7. To enable a temperature correction, the temperature was measured and entered into the meter. Next, the electrode is lifted and gently cleaned with tissue paper. After that, the electrode is dipped into the sample solution and watched for a consistent pH meter reading for up to a minute. After taking the reading, the indicator value should not change for roughly nine minutes.
6) *Determination of COD:* The amount of oxygen consumed when organic matter is oxidized by a potent oxidizing agent is measured by COD. Using a COD digester tube filled with 2 millilitres of sample wastewater, 1 millilitre of $K2Cr2O7$ solution, 2.5 ml of concentrated $H2SO4$, 500 mg of Mercuric sulphate is added and thoroughly mixed. Further the COD digester tube is placed in the Digester for 120 minutes at 150 Degree Celsius. Upon completion of digestion the COD tubes are cooled to room temperature and titrated against 0.1N Ferrous Ammonium sulphate after adding two to three drops of Ferrous indicator. The abrupt colour shift from bluish-green to reddish brown is the endpoint.
7) *Determination of Bacterial Count:* The bacterial count of raw and treated water samples was determined using the pour plate method. To prepare the nutrient medium, 3.9 g of Potato Dextrose Agar (PDA) was dissolved in 100 mL of distilled water, followed by the addition of 2 g of nutrient agar. The solution was heated to boiling until a clear medium was obtained, ensuring complete dissolution of the components. All necessary equipment and glassware, including Petri dishes, beakers, test tubes, pipettes, and the agar medium, were sterilized using an autoclave at 121°C at 15psi for 15-20 minutes to eliminate any microbial contamination. After autoclaving, the prepared agar medium was allowed to cool and subsequently poured into sterile Petri dishes inside a laminar airflow (LAF) chamber to maintain aseptic conditions. Once the agar solidified, water samples (both raw and treated) were serially diluted as required and inoculated onto the plates using the pour plate technique. The inoculated Petri dishes were then incubated at room temperature for 48 hours, allowing bacterial colonies to grow. After the incubation period, the colony forming units (CFU/mL) were counted, and the results were used to assess the microbial load before and after treatment.
8) *EDX characterization:* Energy-dispersive X-ray spectroscopy (EDS) is defined as an analytical technique used for the elemental analysis or chemical characterization of a sample, allowing for the determination of elemental composition and the mapping of the lateral distribution of elements. Energy Dispersive X-ray Spectroscopy (EDX) was performed to analyse the elemental composition of sludge generated from the treatment of Domestic washing machine (DWM) wastewater using Poly Aluminium Chloride (PAC). This analysis helps in identifying the presence of key elements such as aluminium from PAC and other residual elements derived from detergents and surfactants. Sample Preparation: Sludge was collected from treated wastewater after the sedimentation process (Fig.6.a). The sample was oven-dried at 105°C for 24 hours to remove moisture and then finely ground to ensure uniformity (Fig.6.b).

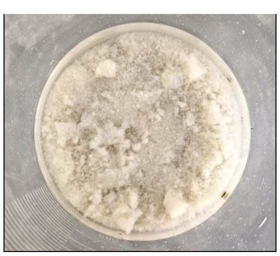


Fig.6.a Sludge Formed After Sedimentation of PAC-Treated Domestic Washing Machine Effluent

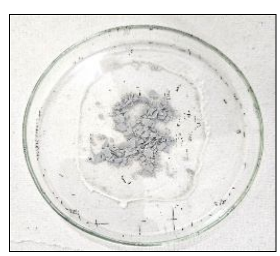


Fig.6.b Oven dried sludge from washing Machine waste water.

## V. RESULTS AND DISCUSSION

### *A. Bentonite-simulated turbid water:*

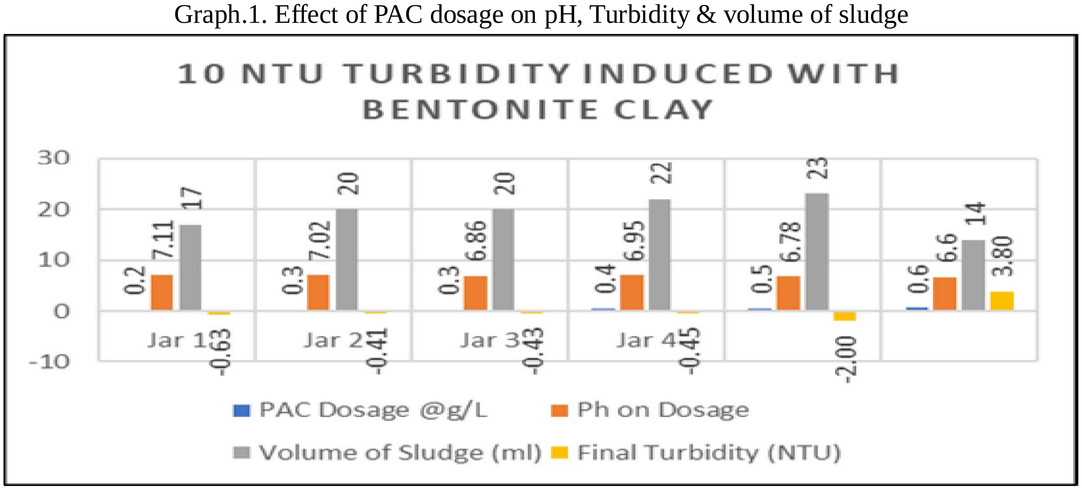
In this study, initially bentonite clay was selected as the turbidity-inducing agent due to its ability to impart a colloidal charge to water, thereby simulating natural suspended solids and increasing turbidity. As supported by Ofir et al., an optimal bentonite concentration of 20 mg/L yields a turbidity of approximately 17.3 NTU, making it suitable for laboratory-scale turbidity induction [11].

To evaluate the performance of Poly Aluminium Chloride (PAC) in turbidity reduction, synthetic turbid water samples were prepared using bentonite clay dispersed in distilled water. Target turbidity levels of *10, 20, 30,* and *40 NTU* were created by adding appropriate amounts of bentonite. Each turbid sample was then treated with varying PAC dosages and turbidity reduction was optimised at *0.5 g/L, 0.45 g/L, 0.60 g/L,* and *1.00 g/L*, respectively. The residual turbidity values recorded for optimum dosage treatment were *-2.00, -5.90, -4.20,* and *-0.02 NTU*, indicating substantial reductions in turbidity across all cases.

The corresponding volumes of sludge generated post-coagulation were *23 mL*, *23 mL*, *24 mL*, and *22 mL*, respectively. These relatively consistent sludge volumes suggest that PAC effectively agglomerated suspended particles, leading to good floc formation and settling.


Fig.7. Floc formation and sedimentation observed after treatment of bentonite clay-induced turbid water with Poly Aluminium Chloride (PAC)

Graph.1. Effect of PAC dosage on pH, Turbidity & volume of sludge



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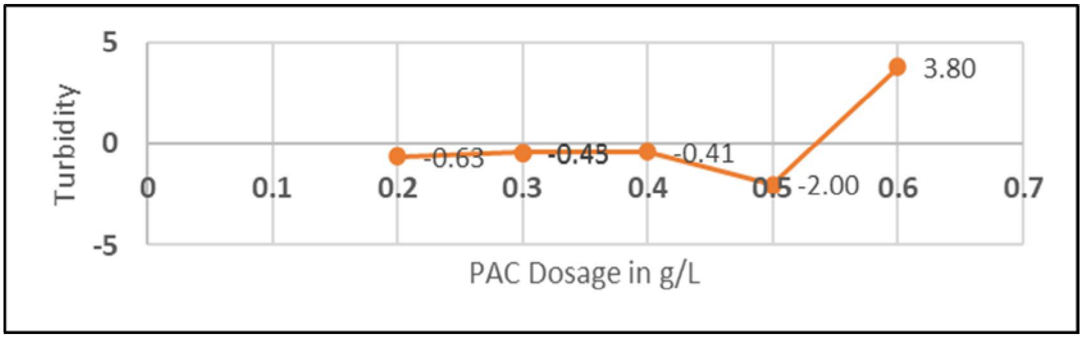
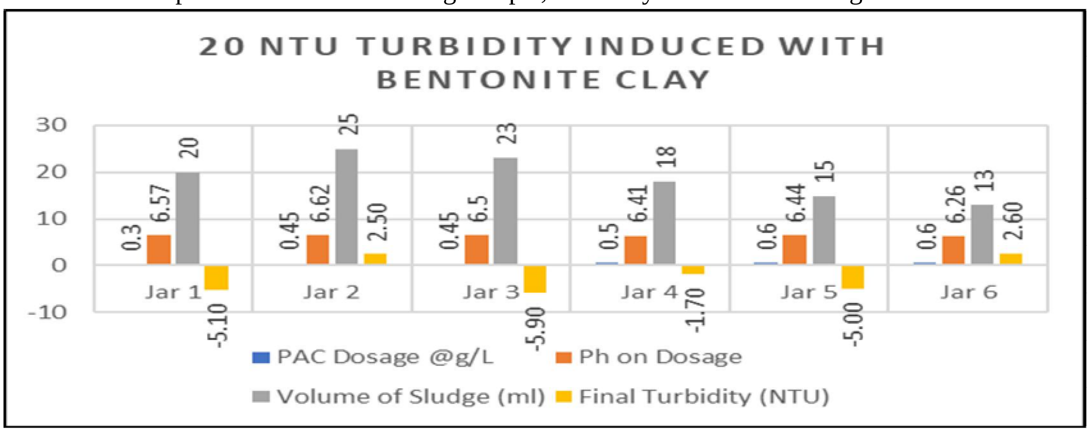
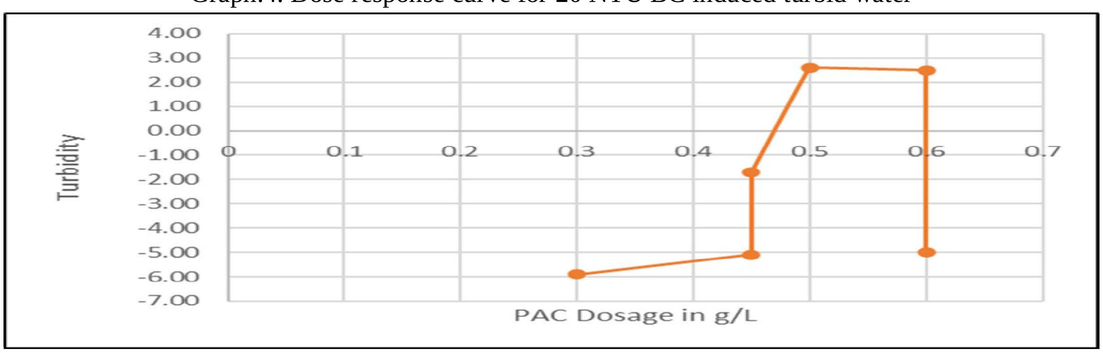
Graph.2. Dose response curve for 10 NTU BC induced turbid water



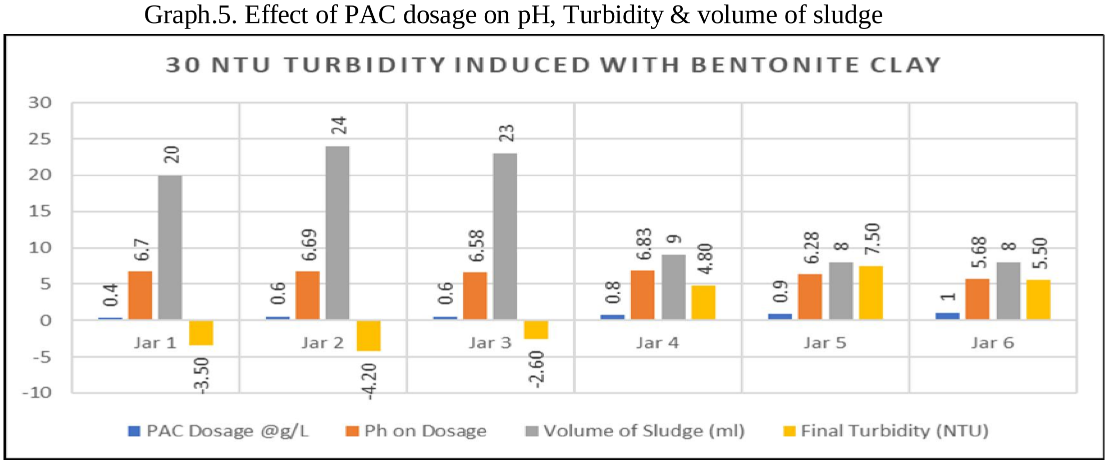

Graph.3. Effect of PAC dosage on pH, Turbidity & volume of sludge




Graph.4. Dose response curve for 20 NTU BC induced turbid water




Graph.5. Effect of PAC dosage on pH, Turbidity & volume of sludge



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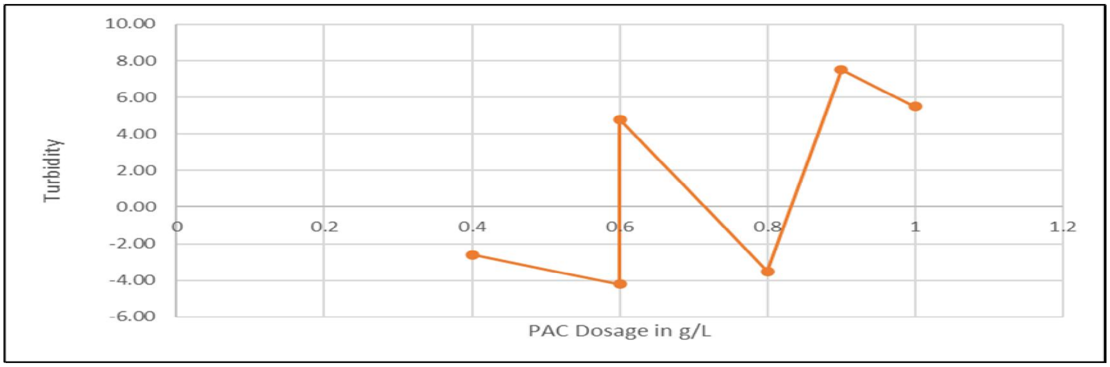
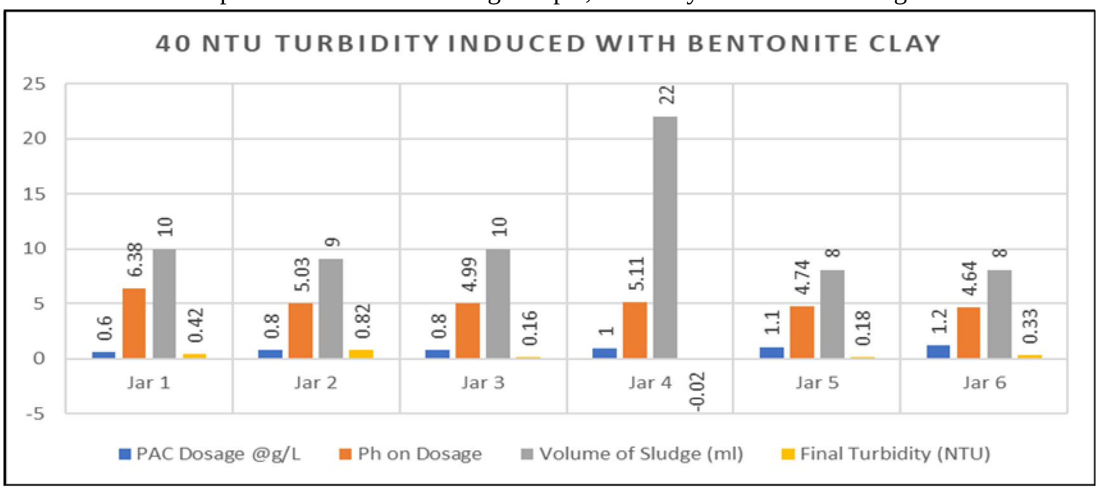
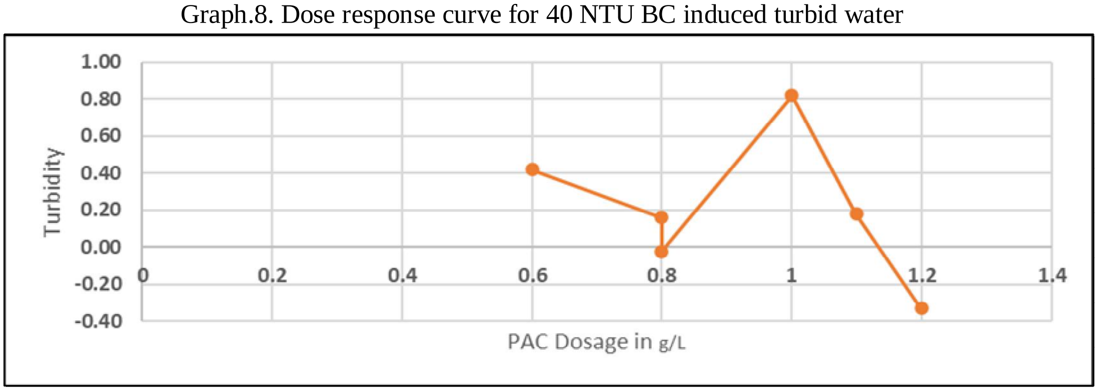
Graph.6. Dose response curve for 30 NTU BC induced turbid water




Graph.7. Effect of PAC dosage on pH, Turbidity & volume of sludge




Graph.8. Dose response curve for 40 NTU BC induced turbid water




*B. Domestic Washing Machine (DWM) Effluent*

The DWM effluent, initially exhibiting a turbidity of *52.2 NTU* and an alkaline pH of *9.97*, was treated using Poly Aluminium Chloride (PAC) after pH adjustment to *7.50* using 0.1 N $H_2SO_4$, ensuring optimal coagulation conditions within the recommended PAC pH range of 6–9. The water samples were treated with varying PAC dosages of *0.30, 0.60, 0.90, 1.20, 1.50*, and *1.80 g/L* (Fig.8.a), yielding residual turbidity values of *60.40, -0.75, -0.25, 22.50, 71.60*, and *68.30 NTU* respectively (Fig.8.b). Interestingly, the negative turbidity values at *0.6* and *0.9 g/L* indicate high clarity, due to the formation of highly settleable flocs and complete removal of suspended particles, validating the effectiveness of PAC at lower dosages. The lowest turbidity was observed at *0.6 g/L*, suggesting this as the most efficient dosage for turbidity reduction. However, higher dosages beyond *1.2 g/L* led to increased turbidity, likely due to restabilization of particles caused by overdosage.

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Sludge generation increased correspondingly with higher PAC dosages, recorded as *12*, *21*, *25*, *27*, *28*, and *26 mL* for the increasing concentrations used. COD levels in the raw domestic laundry effluent were initially found to be *2000 mg/L*, which significantly decreased to *280 mg/L* after treatment, indicating an *86%* reduction in organic load. However, bacterial analysis showed *no reduction* in microbial load, with CFU counts remaining constant at 6000 CFU/mL before and after treatment (Fig. 9.a, Fig. 9.b). These results suggest that while PAC is highly effective in reducing turbidity and COD, it does not significantly impact microbial removal in domestic waste water. Optimal performance was observed at lower PAC dosages, offering substantial reductions in turbidity and COD while minimizing sludge volume.

Fig.8.a. Jar Test Showing Floc Formation in Domestic Wastewater Treated with PAC

Fig.8.b. Clear Supernatant After PAC Treatment of Domestic Wastewater

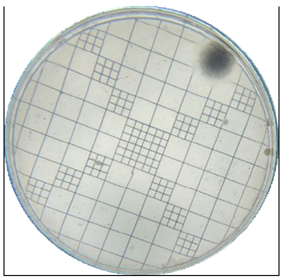


Fig.9. a. Bacterial colony and fungal growth in DWM Effluent sample at Dilution Factor 10^-3

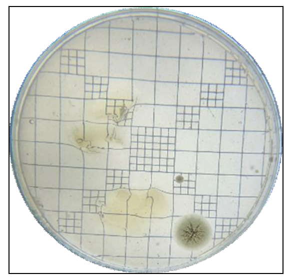
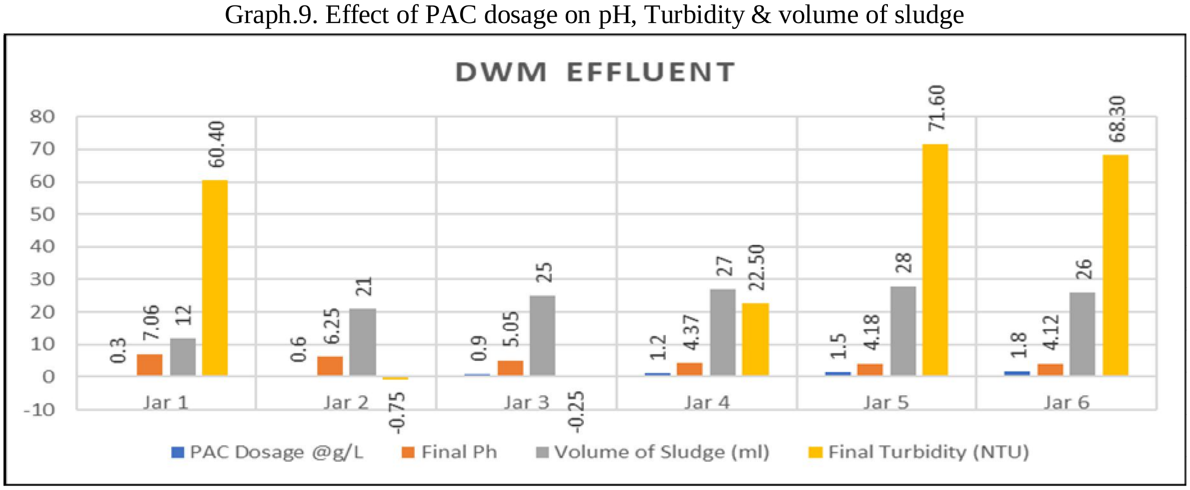


Fig.9. b. Bacterial colony and fungal growth in DWM Effluent sample Treated with PAC at Dilution Factor 10^-3

Graph.9. Effect of PAC dosage on pH, Turbidity & volume of sludge



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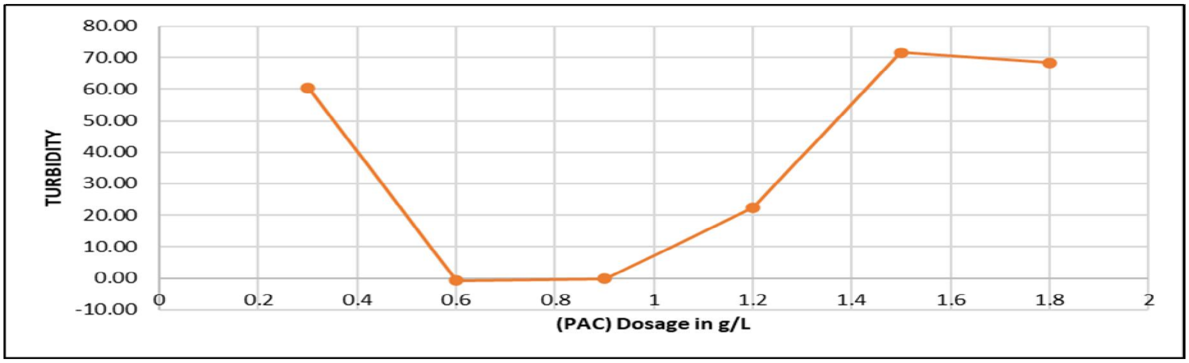
Graph.10. Dose response curve for DWM Effluent




*C. Urban Lake (UL) Water*

The UL fresh water sample, with an initial turbidity of *2.5 NTU* (Fig.10.a), was subjected to treatment using varying dosages of Poly Aluminium Chloride (PAC). The raw water had a pH of *8.52*, which falls within the optimal operating range of PAC (typically pH 6–9); hence, no pH adjustment using 0.1 N $H_2SO_4$ was necessary.

Due to limited sample volume, only four PAC dosages were tested: *0.025 g/L*, *0.035 g/L*, *0.045 g/L*, and *0.055 g/L*. The corresponding residual turbidity values after treatment were *0.20*, *-0.16*, *-0.26*, and *-0.56 NTU*, respectively (Fig.10.b). The lowest turbidity *(-0.56 NTU)* was observed at a PAC dosage *of 0.055 g/L*, indicating it as the most effective dose under the given conditions. The sludge volume generated during treatment increased with PAC dosage, recorded as *7 mL*, *8 mL*, *8.5 mL*, and *9 mL*, respectively.

The raw urban lake water sample exhibited a high COD value of *2800 mg/L*, indicating a substantial organic load likely originating from untreated sewage or organic runoff. Following treatment with PAC, the COD was significantly reduced to *40 mg/L*, reflecting a *98.57%* reduction. This highlights the remarkable effectiveness of PAC in removing organic pollutants in addition to turbidity. In terms of microbial contamination, the bacterial load initially measured at *6000 CFU/mL* was reduced to *2000 CFU/mL* after treatment (Fig. 11.a, Fig. 11.b). This substantial reduction suggests that PAC also contributes to microbial removal, likely through the enmeshment of bacterial cells within flocs, which are then removed during sedimentation. Overall, these findings confirm the high performance of PAC in treating urban lake water. An optimal dosage of *0.035 g/L* was identified under the test conditions, offering an effective balance between pollutant removal efficiency and moderate sludge generation.

Fig.10. a. Urban Lake Water Sample Before PAC Treatment

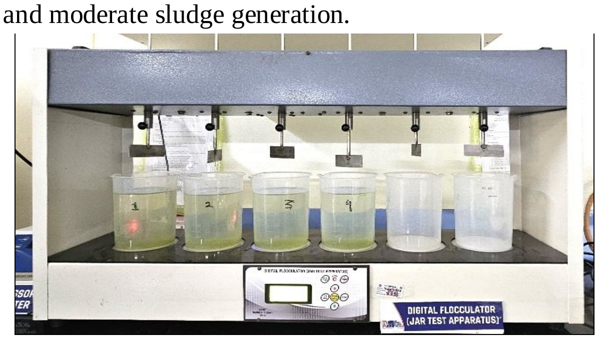



Fig.10.b Clear Supernatant After PAC Treatment of UL water

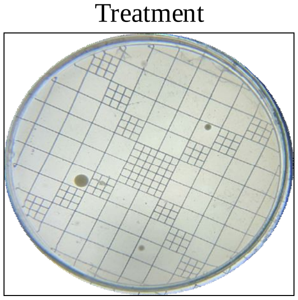


Fig.11.a Bacterial colony growth in UL water sample at Dilution Factor 10^-3

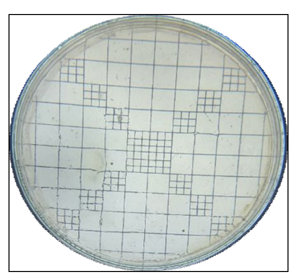


Fig.11.b Bacterial colony growth in UL Water Treated with PAC at Dilution Factor 10^-3

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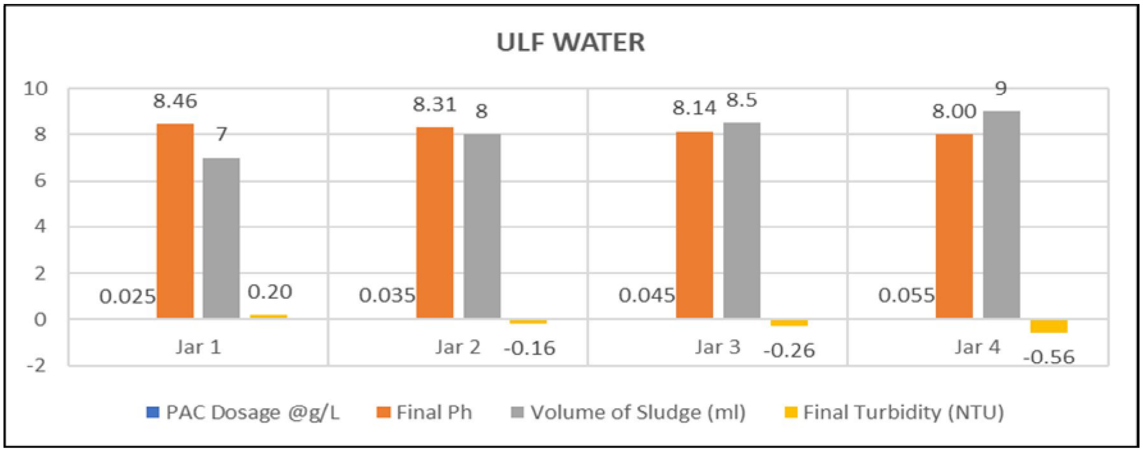
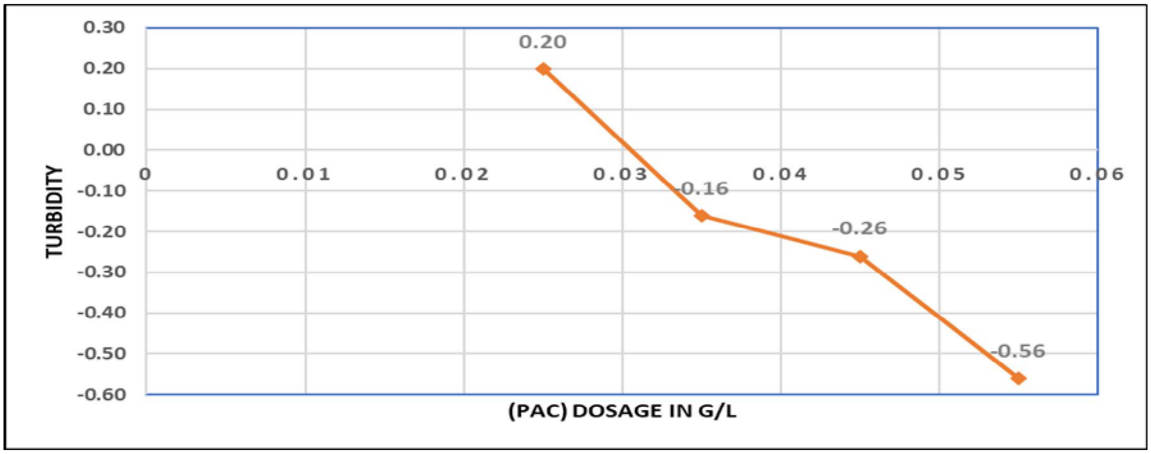
Graph.11. Effect of PAC dosage on pH, Turbidity & volume of sludge




Graph.12. Dose response curve for UL water




*D. EDX Characterization of DWM effluent sludge*

The EDX (Energy Dispersive X-ray) analysis reveals the elemental composition of *sludge generated* from washing machine wastewater (Fig.12.b), which includes residues from detergents, fabrics, dirt, and coagulant PAC was used.

Fig.12.a SEM-EDX Image of Sludge Obtained After PAC Treatment of Domestic Washing Machine Effluent

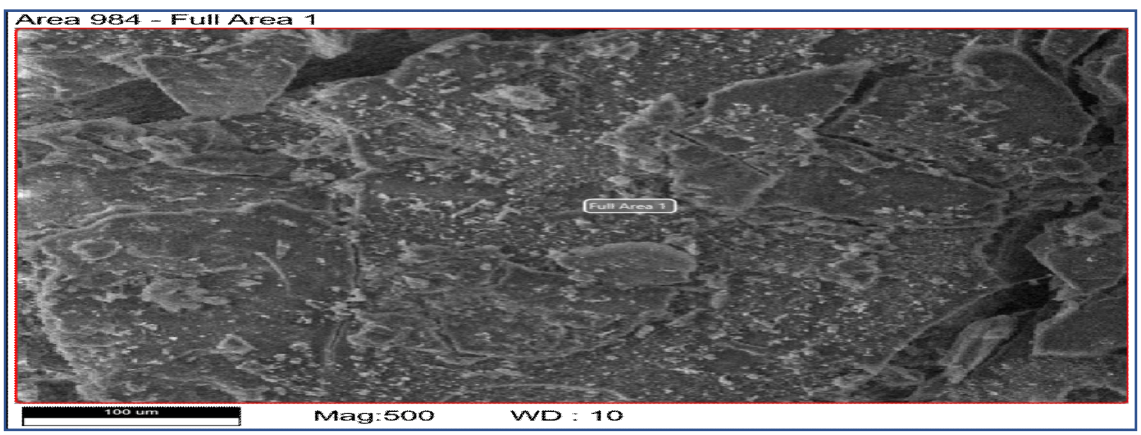


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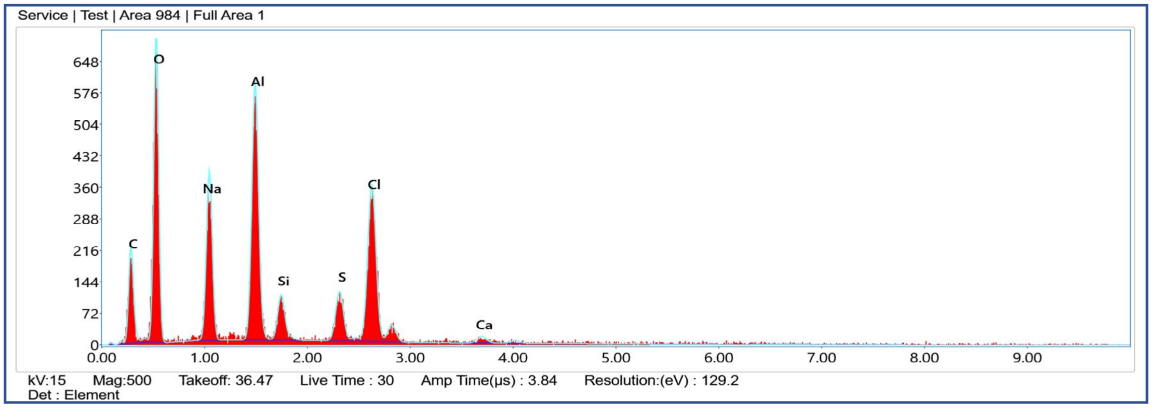
Fig.12.b EDX Spectrum Showing Elemental Composition of Sludge from Treated Domestic Washing Machine Effluent




## VI. CONCLUSION

The study successfully evaluated the effectiveness of Poly Aluminium Chloride (PAC) in treating various water types synthetic bentonite-induced turbid water, domestic washing machine (DWM) effluent, and urban lake (UL) water focusing on the removal of turbidity, chemical oxygen demand (COD), and microbial contaminants. The findings confirmed that PAC is a highly efficient coagulant, particularly in reducing turbidity and COD across all sample types. In synthetic turbid water up to *40NTU*, PAC achieved near-complete turbidity removal at dosages ranging from *0.45 to 1.0 g/L*, with final turbidity values dropping below 0 NTU due to enhanced clarity.

Similarly, in DWM effluent, turbidity was reduced from an initial *52.2 NTU* to a minimum of *-0.75 NTU* at an optimal dosage of *0.6 g/L*, while COD was reduced from *2000 mg/L* to *280 mg/L*, reflecting an *86%* reduction. For UL water, PAC reduced turbidity from *2.5 NTU* to *-0.16 NTU* at an optimal dosage of *0.035 g/L* and COD from *2800 mg/L* to just *40 mg/L* an impressive *98.57%* reduction demonstrating its strong potential for treating polluted surface water.

Microbial analysis revealed *mixed outcomes*. While DWM effluent showed no reduction in bacterial load (remaining at *6000 CFU/mL* before and after treatment), the urban lake water showed a reduction from *6000 CFU/mL to 2000 CFU/mL*. These results indicate that PAC alone may not be sufficient for effective bacterial removal in heavily contaminated greywater but can contribute to microbial reduction in less polluted water, likely due to enmeshment of microbial cells in flocs and their removal through sedimentation. Thus, for complete microbial control, especially in greywater treatment, PAC should be supplemented with a disinfection step. The influence of pH and coagulant dosage was critically observed throughout the study. Optimal performance occurred within the effective PAC pH range of *6–9*. In DWM effluent, pH adjustment from *9.97* to *7.50* using 0.1 N $H_2SO_4$ was necessary for efficient flocculation, with the final pH at optimal dosage recorded at *6.25*. In contrast, urban lake water treatment did not require pH adjustment as the raw sample pH of *8.52* was already within the effective range. Overdosage beyond optimal PAC levels resulted in particle restabilization and higher residual turbidity, emphasizing the need for careful dosage control. Sludge generation trends were consistent across all samples, increasing with dosage but remaining within manageable limits, ranging from *7 mL* in UL water to *28 mL* in DWM effluent.

Further insight into the treatment process was gained through Energy Dispersive X-ray (EDX) characterization of the sludge generated after PAC treatment. The elemental composition revealed high concentrations of aluminium *(11.5%)*, confirming the presence of residual PAC, and significant amounts of carbon *(27.3%)* and oxygen *(32.5%)*, indicating organic matter such as surfactants and microbial biomass. The detection of sodium *(10.2%)*, sulphur *(3.2%)*, and chlorine *(12.2%)* confirmed the presence of detergent-related compounds, while silicon and calcium suggested traces of soil particles and fabric residues. These findings validate the removal of both organic and inorganic pollutants during coagulation.

In conclusion, the study demonstrates that PAC is a highly effective coagulant for turbidity and COD reduction, with partial efficacy in microbial removal. The success of treatment depends heavily on pH control and optimal coagulant dosage. The combination of performance data and EDX analysis provides strong evidence for PAC's applicability in practical water treatment scenarios, particularly when integrated with complementary processes for complete contaminant removal. Beyond laboratory validation, the findings highlight the significance of PAC for decentralized wastewater treatment, especially in commercial establishments such as *laundries*, *hostels*, and *residential complexes* that discharge untreated effluent into drains and waterbodies.

By adopting PAC-based treatment at the source, such facilities can substantially reduce the organic and particulate load entering municipal sewers, thereby easing the burden on centralized treatment plants and minimizing pollution of urban water bodies. This approach promotes sustainable water management while offering a cost-effective solution adaptable to both urban and semi-urban contexts.

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