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*Research Article*

# Comparative study of Poly Aluminum Ferric and Poly Aluminum Chloride Performance for Turbidity Removal from River Water

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**Abstract**
Due to urbanization and industrial development, pollution of water bodies has become a serious concern. Coagulation and flocculation system is the conventional method of removal of the contaminants from raw water. In this study, the effectiveness of PAF and PAC was evaluated at different turbidity levels in order to find optimal operational conditions for low to high turbidity river waters. A set of jar test experiments was conducted to find the optimal coagulant dosage for turbidity removal in Babolrood River samples, Results demonstrated that coagulation process can assure turbidity removal from low to high turbidity waters (i.e., 18.3, 39.2, 72.5, and 136 NTU) effectively using relatively low levels of PAF and PAC (2.5 to 16 ppm). Results showed that turbidity removal is dependent on coagulant dosage, as well as initial turbidity of water for both used coagulants. The highest turbidity removal efficiency was within 96.6-98.3% for PAF and PAC over the applied range of turbidity. Both applied coagulants demonstrated promising performance in turbidity removal from water; however, PAC showed better performance compared to PAF as the optimal dosage of PAC for maximum turbidity removal was 6.5 ppm, which is lesser than 12.5 ppm of PAF. The results of the current study can be used as a baseline data for river water treatment facilities which uses these two types of coagulants.
**Keywords:** Water treatment, Coagulants, Poly aluminum ferric, Poly aluminum chloride, Turbidity

## Introduction

Water generally contains suspended and colloidal solids from land erosion, decayed vegetation, microorganisms, and color-producing compounds (Skaf et al., 2020; Zhang et al., 2020). Increasing population growth, improvements of living standards, and industrial and commercial development are factors that increase the communities water consumption (Ding et al., 2020; Khan et al., 2019). Surface water consists of colloidal impurities which produce turbidity and color which indicate the poor quality of the water (Liu et al., 2020). Therefore, it is necessary to add chemicals that help to settle these colloidal impurities in a short period of time (Wei et al., 2017). These chemicals are named coagulants and are used for coagulation and flocculation in water treatment (Adeniyi et al., 2022).

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Coagulation and flocculation system is a part of the water treatment process whereby the colloidal particles are made to agglomerate and settle down at the bottom of the tanks as flocs (Ahmad et al., 2021; Guo et al., 2020). Coagulants are necessary for optimizing coagulation which could remove turbidity and organic matter (Pirhashemi et al., 2018). Proper coagulation is essential for good filtration and disinfection (Mohan et al., 2019). Optimizing coagulation is the most cost-effective way to reduce treated water turbidity and disinfection (Zhou et al., 2018). There are several reagents available in the market. But it is important to select the best quality, effective coagulant to treat water efficiently (Chee et al., 2016). Commonly used coagulants in water treatment are (Aibinu et al., 2022; Hebbar et al., 2018; Nandhini et al., 2019):

- Coagulants based on aluminum, such as aluminum sulfate ($Al_2(SO_4)_3.18H_2O$), sodium aluminates ($Na_3AlO_3$), poly aluminum chloride [$Al_2(OH)xCl_6$-x], potash aluminum (AlK $(SO_4)_2.2H_2O$), and ammonia aluminum ($AlNH_4(SO_4)_2.12H_2O$).
- Coagulants based on iron, such as ferric sulfate ($FeSO_4.7H_2O$), chlorinated coppers, and ferric chloride ($FeCl_3$).
- Polyelectrolytes, which are long-chain synthetic polymers with a high molecular weight.

In the treatment process, poly aluminum ferric (PAF) is widely used as a coagulant regent in the coagulation process (Gandiwa et al., 2020). Considering all the steps in the treatment process, the cost of using alum is an indirect expense in the following activities in the treatment: pH adjustment, sludge treatment and sludge disposal (Baytar et al., 2020; Madhura et al., 2021).

In order to minimize the above problems and achieve a cost-effective and efficient treatment process the use of a proper coagulant is vital in the treatment process (Enfrin et al., 2019). Poly aluminum chloride (PAC) is one of the most efficient water treatment chemicals utilized today (Cheng et al., 2021). It is widely used in both potable water and wastewater treatment because it provides high coagulation efficiency (Xia et al., 2020) and it has the widest pH and temperature application ranges compared to other water treatment chemicals (Oriekhova and Stoll 2018; Azari et al., 2021).

The main objective of this research was to compare the effectiveness of PAF and PAC in reducing turbidity levels in river water. Their performance was evaluated at different coagulant dosages in order to find optimal operational conditions for low to highly turbidity water samples.

## Material and Methods

### *Experimental method*

This study was designed to conduct full factorial experiment with two fixed factors, including different turbidity levels and PAF and PAC dosages. Several numbers of jar tests were conducted using six sets of gang-mixer jar tests by using Babolrood River water. Turbidity removal was used as performance indicators for coagulation control in this study.

### *Preparation of coagulant chemicals*

Industrial grade PAF (16%) and PAC (28%) are selected as chemical coagulants in water treatment. Stock solutions of PAF and PAC were made at an 1% strength (weight in volume, w/v). Coagulant solution was freshly prepared by dissolving 10 g of coagulant in 1 L of distilled water for making 1% solution of coagulant and dilutes it with distilled water (APHA, 2005).

*Water sample collection*

12 L of raw water samples were collected from Babolrood River. The Babolrood River is one of the principal rivers in the southern Caspian Sea basin in the north of Iran. This waterbody is contaminated by pollutants resulting from anthropogenic activities such as mining, agricultural runoff, wastewater discharging, industrial wastewater streams, or landfill processes (Fallah et al., 2022). Collected wastewater samples were stored in the refrigerator at 4 ˚C to minimize the possibility of decomposition prior to treatment.

*Coagulation jar tests*

All coagulation studies were conducted in jar test apparatus (Phips and Bird, USA) by using raw water under the ambient temperature (25±2 ˚C). Jar test apparatus having six flat blade stirrers (each 7.6 × 2.5 $cm^2$) driven by 0.05 HP motor with an induced speed range of 10 to 400 rpm was used to assess PAF and PAC in coagulation of colloids and dissolved particles. Borosil glass beakers of 1 L capacity were used for all the experiments. The field conditions were simulated in the laboratory in jar test apparatus with two minutes for rapid mixing of coagulants with raw water, 10 minutes for coagulation and flocculation, and 10 minutes for sedimentation of flocs. The jar test procedure for optimizing the dosage of coagulant includes the following steps:

- While rapidly mixing the raw water, six different dosages of coagulants were added to each jar containing the water from the same source (Figure 1).
- The coagulants were rapidly mixed at high velocity for two minutes with 180 rpm at the maximum possible mixing intensity.
- The stirring speed is reduced while slowly mixing the suspensions at 180 rpm to 120 rpm for four minutes.
- The stirring speed is further reduced while more slowly mixing the suspensions at 120 rpm to 40 rpm for six minutes.
- The stirring apparatus is stopped to allow the floc to settle for 10 minutes.
- The turbidity of the water samples was measured.

**Figure 1.** Removal of turbidity at different dosages of coagulants using jar test

*Optimal coagulant dosage selection*

PAF and PAC were tested for removal at the selected dosages at different turbidity levels. After 10 minutes of settling, the optimal PAF and PAC doses were apparent for water samples. Supernatant samples were taken from 20 mm below the water surface for turbidity measurement. Maximum turbidity removal was the parameter used to select the optimal dose; but, in some cases the second largest turbidity removal was selected as the ideal dosage. It was noted that the pH did not influence the selected dosages of the water samples.

*Analytical method*

The turbidity meter (HACH 2100Q) used for turbidity measurement. Testing of the water samples pH was undertaken before and after jar test treatment with both types of coagulants by using a pH meter (Metrohm 691). Color was measured by using a Hach DR 2800 spectrophotometer.

## Results and discussion

*Characteristics of raw water samples*

Table 1 shows the raw water parameters in Babolrood river. Water quality parameters were measured weekly during sampling period of fall 2022 (November). As can be seen from Table 1, turbidity of the raw water samples varies every week depending on upstream activities and conditions.

**Table 1.** Characteristics of Babolrood water samples (November 2022)

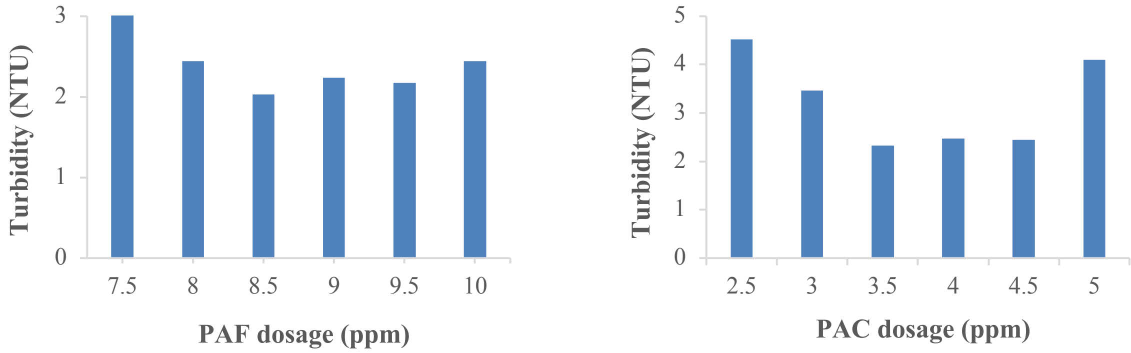
| Water samples | Turbidity (NTU) | Color (Hu) | pH | Alkalinity | Temperature (˚C) |
|---|---|---|---|---|---|
| 1 | 18.3 | 40 | 6.3 | 24 | 26.8 |
| 2 | 39.2 | 70 | 6.5 | 20 | 25.6 |
| 3 | 72.5 | 90 | 6.5 | 15.5 | 26.2 |
| 4 | 136 | 100 | 6.1 | 15 | 25.4 |

*Coagulant performance*

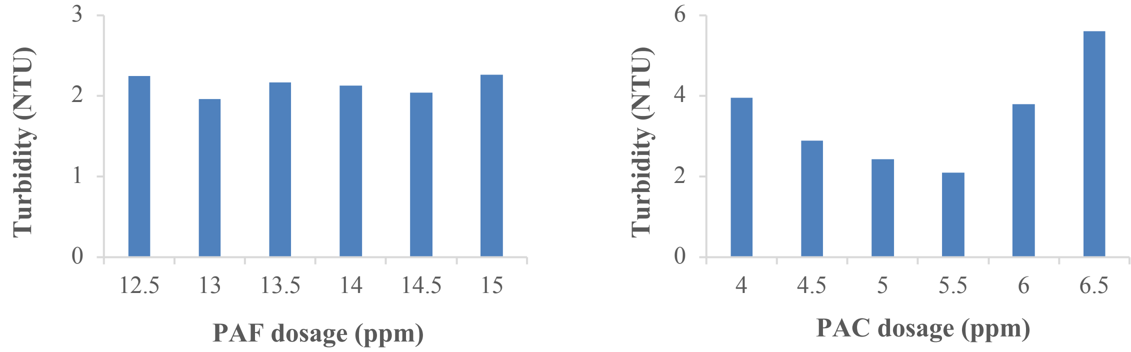
Experiments were carried out to observe the performance of the PAF and PAC on the clarity of raw water samples at different levels of turbidity i.e., 18.3, 39.2, 72.5, and 136 NTU. The effects of increasing coagulant dosages on water samples were also determined (Figure 2). Figure 2 shows the increased removal of water impurities with an increase in the dosage of both types of coagulants. The comparative performance of PAF and PAC is summarized in Table 2. Good removal efficiency was recorded for PAC in all ranges of turbidity than PAF. Both coagulants performed well at higher turbidities. However, the PAC produced the lowest water impurities and showed the better results than either of the PAF coagulants.

**Table 2**. The comparison of PAF and PAC optimal dosages for turbidity removal in Babolrood River

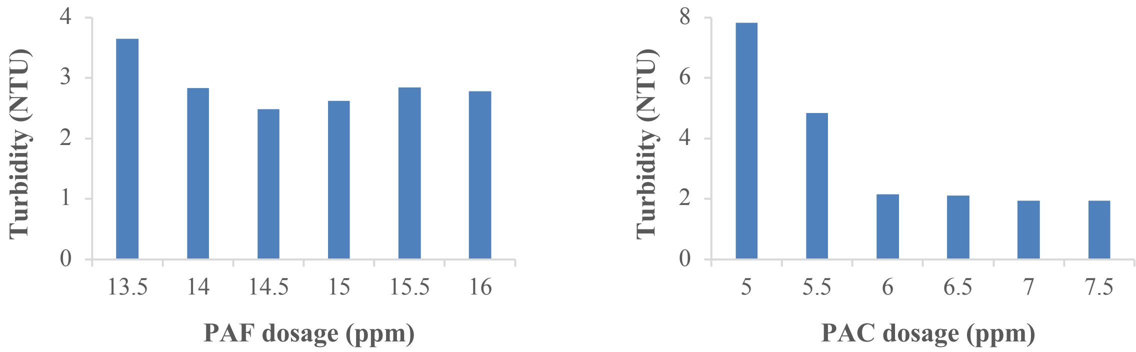
| Raw water turbidity (NTU) | PAF | | PAC | | PAC/PAF optimum dosage (%) |
|---|---|---|---|---|---|
| | Optimum dosage (ppm) | Turbidity reduction (%) | Optimum dosage (ppm) | Turbidity reduction (%) | |
| 18.3 | 8.5 | 88.9 | 3.5 | 87.3 | 41.18 |
| 39.2 | 13 | 95.0 | 5.5 | 94.6 | 42.31 |
| 72.5 | 14.5 | 96.6 | 6.5 | 96.6 | 44.83 |
| 136 | 13.5 | 98.3 | 6.5 | 98.3 | 48.15 |



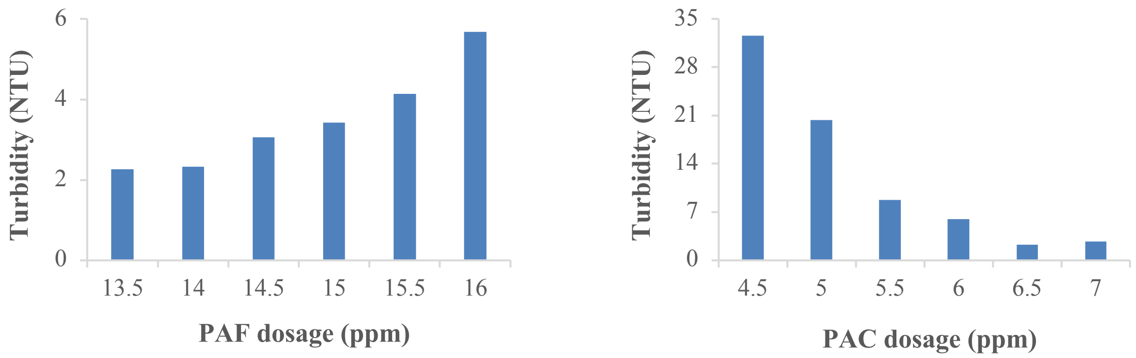

(a)




(b)




(c)




(d)

**Figure 2.** Comparative performance of PAF and PAC for turbidity removal at initial turbidity levels of (a) 18.3 NTU, (b) 39.2 NTU, (c) 72.5 NTU, and (d) 136 NYU.

## Conclusion

Although, there are many types of coagulants available to treat water, opting the most effective coagulant for a particular water still largely depends on the outcome of laboratory jar testing. PAF, a known coagulant for water treatment was investigated for turbidity removal from Babolrood River treatment in the present study. PAC as a conventional coagulant was also applied to the water samples for performance comparison. The optimum dosage for turbidity removal was found 6.5 and 13.5 ppm, respectively, for PAC and PAF resulting in the maximum turbidity removal (98.3%).

The highest turbidity removal efficiency was more than 98% for PAC and PAF over the different levels of turbidity (i.e., 18.3, 39.2, 72.5, and 136 NTU). Optimal coagulant dosage was lower for PAC compared to PAF at maximum turbidity removal efficiency. From the results of the study, it is concluded that the use of PAC for coagulation resulted in better turbidity removal than PAF.

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