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Study of *Aloe vera* combined with PAC Application for Reducing Pollutants in Water

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Abstract
Poly Aluminum Chloride (PAC) is a chemical that is frequently utilized in the treatment of drinking water. It is therefore essential to investigate methods of reducing the dosage of PAC in conjunction with natural ingredients that have the potential to adsorb pollutants in water. This research employs a combination of PAC and aloe vera, utilizing the optimal composition identified in previous research. The research was conducted on a laboratory scale using raw water samples of river water that had been intentionally contaminated with iron. The pollutant parameters measured were iron, organic matter, and ammonia. These parameters were selected as they are likely to be affected by the addition of aloe vera. The results of the treatment using jar tests were evaluated by comparing the quality of the initial water sample, the use of PAC alone, and the use of a combination of PAC and aloe vera. The experimental results demonstrated that the combination of PAC and Aloe vera exhibited superior efficacy in reducing iron levels compared to PAC alone. However, this combination also resulted in a notable increase in organic matter levels in the water samples.
Keywords: *aloe vera, ammonia, coagulation, flocculation, iron, organic matter, pac*

Abstrak
Bahan kimia PAC (Poli Aluminum Klorida) sudah umum digunakan dalam proses pengolahan air minum. Untuk itu perlu diteliti upaya untuk mengurangi dosis penggunaan PAC dengan bahan alami yang berpotensi adsorpsi polutan dalam air. Penelitian ini menggunakan bahan kombinasi antara PAC dengan *Aloe Vera* dengan komposisi optimum dari hasil penelitian sebelumnya. Penelitian dilaksanakan skala laboratorium dengan sampel air baku air sungai yang dibuat dengan sengaja ditambahkan Besi. Parameter polutan yang diukur adalah besi, serta parameter zat organik dan ammonia sebagai parameter yg mengantisipasi adanya dampak penambahan *Aloe* vera. Hasil perlakuan dengan menggunakan Jar tes dilakukan dengan pengamatan pada perbandingan antara kualitas sampel air awal, penggunaan PAC saja dan penggunaan kombinasi PAC dan *Aloe vera*. Hasil percobaan menunjukkan bahwa penggunaan kombinasi PAC dan *Aloe vera* dibandingkan dengan penggunaan PAC saja menghasilkan penurunan kadar besi yg lebih baik, penurunan ammonia yang sama, namun meningkatkan kadar zat organic dalam sampel air
Kata Kunci: *aloe vera, besi, amoniak, flokulasi, koagulasi, pac, zat organik*

1. Introduction

The water quality of surface water sources is deteriorating due to alterations in land use and community activities upstream. The decrease in water availability poses a risk to the local water supply and emphasizes the necessity for efficient water treatment remedies. The present utilization of PAC (Poly Aluminium Chloride) for water purification is efficacious, although it may present hazards to both the environment and human well-being, such as the disturbance of river microorganism equilibrium or enhancing the chemical reactions in water. On the other hand, Aloe vera, which is extensively cultivated and easily accessible in Indonesia, namely in regions such as Pontianak and East Java, shows potential as a viable substitute for bio-coagulants. Using *Aloe vera* can decrease the need for PAC, which could result in economic savings and reduced environmental impact. It can effectively handle important issues including turbidity and pH balance in water sources [1] .

Aloe vera is selected as coagulant because it propagates very rapidly making it feasible to cultivate on a large scale without difficulty. Furthermore, *Aloe vera* is not considered a hazardous plant, instead, it is used as a raw material in food and beverage products, hair care, wound healing, and skin treatments [2]. Aloe vera is a plant that has been known for thousands of years and contains mucilage, which can be used as a coagulant [3]. The mucilage in Aloe vera contains polygalacturonic acid, which has been demonstrated

to reduce water turbidity [4]. Polygalacturonic acid serves as a coagulant agent through a process of adsorption and bridging. This mechanism gathers dispersed particles towards the polygalacturonic acid, leading to the aggregation of these particles into flocs in the water[4]. The cationic COOH (carboxyl) group in Aloe vera assists in the binding of suspended and colloidal solids, thereby improving water quality. This property of *Aloe vera* promotes the aggregation of these particles, enhancing the water purification process[5]. Additionally, *Aloe vera is* chosen as a bio-coagulant due to its ease of cultivation and availability for large-scale propagation. It thrives in regions with moderately long dry seasons, making it an efficient species for water utilization[6].

Previous studies have explored *Aloe vera* as a natural coagulant for drinking water treatment, using it in both powdered and gel forms. Powdered *Aloe vera* reduced turbidity by 28.23%, and the gel form by 87.84%[7]. Further research at a water treatment plant assessed the effectiveness of these coagulants by measuring water quality parameters such as turbidity, pH, alkalinity, and organic matter. Results showed that these coagulants significantly improved coagulation efficiency compared to raw materials, with the treated water meeting standards for turbidity. The functional groups responsible for the coagulation test involved stirring water samples at different speeds and concentrations of coagulants, followed by settling and filtration process to analyse the treated water[8].

In the synthetic water samples application, *Aloe vera* showed effective coagulation at high Fe/NOM ratios. NOMS inhibited Fe hydrolysis at low ratios, reducing floc formation and NOM removal. Calcium improved Fe hydrolysis, increased zeta potential, and enhanced NOM removal[9]. Applying *Aloe vera* to the wastewater sample from palm oil mils showed that the optimum conditions could remove the turbidity with the efficiency was 82.78%. Under the same conditions, TSS removal efficiency was achieved by 83.08%, and COD was reduced by 33.76% [10]. The research in the drinking water process showed that the combination application of PAC and $FeCl_3$ reduces OMP adsorption efficiency. Increasing PAC dosage and extending contact time improved OMP removal. The high NOM concentration affected adsorption by competing for sited. Desorption during sedimentation reduced efficiency by >30% [11]. Overall, natural coagulants like *Aloe vera* present promising environmentally friendly alternatives to synthetic chemicals in water treatment, contributing to more sustainable practices.

This previous research has been crucial in inspiring the authors to determine the optimal dosage of *Aloe vera* for the coagulation and flocculation process, as well as the appropriate mixing speeds for jar test experiments. The optimum combination dosage of *Aloe vera* liquid and PAC to reduce turbidity, and maintain pH effectively has been reported as 180 ppm of *Aloe vera* liquid in combination with 17 ppm of PAC in the river water sample applications [1].

This study aims to elaborate more on the examination of the practicality of replacing or reducing the usage of PAC with the application of a combination of PAC and *Aloe vera* with a focus on parameter organic matter, Iron, and Ammonia as the key parameters of drinking water standard.

2. Material and Methods

Research Frame Work

The research was conducted in stages as mentioned in **Figure 1** that started with problem identification and finished with a conclusion.

Sampling Location and Method

River water samples were collected from the points at the raw water intake tank of the Water Treatment Plant with the water sources coming from the West Tarum Canal at Cikarang Bekasi (coordinate is 6°17'37"S 107°08'20" E, see **Figure 2**). The collection sample was carried out eight times for separate experiments conducted from January until May 2024.

The sampling activities followed the random sampling techniques set by the SNI 6989.59:2008 standard which prescribes a non-biased method of selecting sampling points without predefined coordinates to capture an authentic representation of the water quality fluctuations over time. Upon collection, these samples were promptly transferred to a laboratory setting where they underwent analytical testing.

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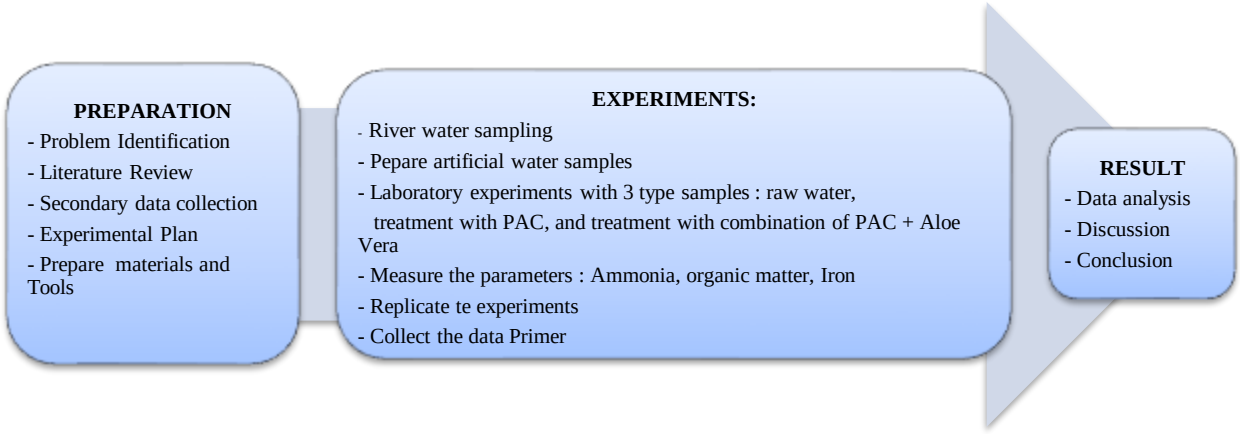

Fig. 1: Research framework

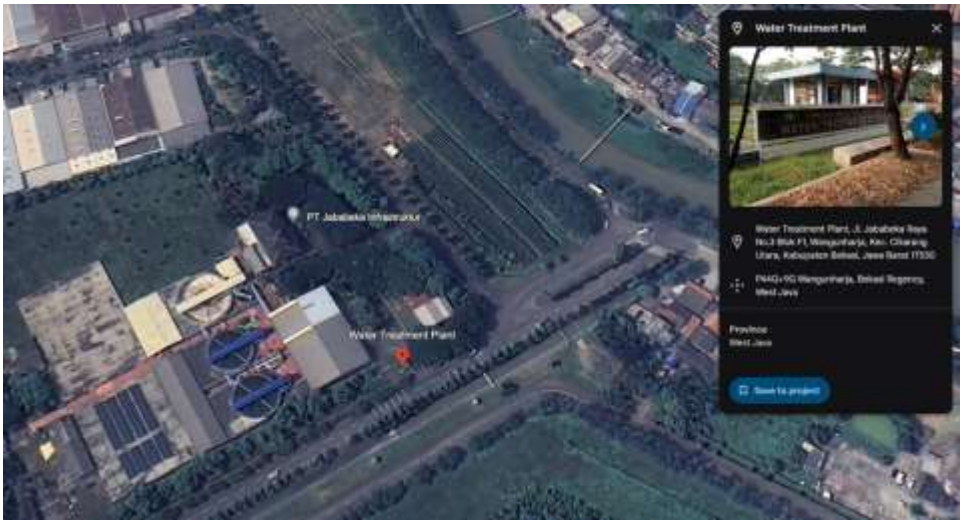

Fig. 2: Location map of raw water sampling

Laboratory Analysis Method

The research was conducted on a laboratory scale. The primary data was collected for parameters organic matter, ammonia, and Iron. The methods of laboratory analysis and their references are mentioned in **Table 1** including the value of drinking water standard issued by Ministry of Health no 2, year 2023 of water quality standard. From Table 1 can be seen that the maximum allowable concentration of Iron (Fe) is 0.2 mg/L. Ammonia and organic matter are also measured in this research though it is not stated in the water quality standard. This is because using organic materials such as Aloe vera needs to anticipate its effect on other parameters like organic matter and ammonia.

Table 1. Methods of laboratory analysis

No	Parameter	Method	Unit	References	Standard
1	Ammonia	Phenate	mg/L	APHA, AWWA, and WEF. 2012, Standard Methods for The Examination of Water and Wastewater, section 4500-NH_3	-
2	Organic Matter	Titrimetric	mg/L	SNI 06-6989.22-2004	-
3	Iron (Fe)	Phenanthroline Method	mg/L	APHA, AWWA, and WEF. 2012, Standard Methods for The Examination of Water and Wastewater, section 3500-Fe	< 0.2

Hypothesis and Statistical Analysis Method

The laboratory concentration results (mg/L) for organic matter, ammonia, and iron (Fe) concentration were statistically analyzed using One-Way ANOVA (Single Factor). This method is employed to determine whether there is a significant difference in reduction in ammonia, organic matter, and iron parameters

among the various treatments in the experiments, specifically comparing the PAC-only treatment to the combination of *Aloe vera* and PAC.

The hypothesis for this analysis is as follows:

H0: $\mu 0 = \mu a$, indicating no significant difference in the parameter observed between the treatment that uses PAC only and the combination o*f Aloe vera* and PAC.

Ha: $\mu a \leq \mu 0$, indicating a significant difference in the parameter observed between the two treatments. The alternative hypothesis in the One-Way ANOVA test utilizes a two-tail hypothesis test with variance which merely indicates differences without considering whether one treatment is higher or lower than the other.

Experimental Design

To evaluate the potential application of *Aloe vera* as a coagulant in the drinking water process, a series of experiments were conducted. The independent variable in these experiments was the type of coagulant used, which included *Aloe vera* and PAC. The dependent variables measured included organic matter, ammonia, and iron. The combination dosages for PAC and *Aloe vera* and application of PAC only were derived from previous research which was 26 mg/L of PAC only and a combination of 17 mg/L of PAC + 80 mg/L of *Aloe vera*.

The experiment was done by jar test method with rapid mixing at 160 rpm for 3 minutes followed by slow mixing at 30 rpm for 20 minutes, and sedimentation time by 30 minutes before measuring the independent parameters

Data Collection

In this research, the primary data is gathered by the author from the source. This involves conducting laboratory experiments to evaluate several key indicators of water quality, such as ammonia concentration, the presence of organic matter, and the amount of iron in samples obtained from the water samples. The research is structured around a series of eight distinct laboratory sessions, each designed to assess the capability of *Aloe vera* as a coagulant in the water treatment process. The success of using *Aloe vera* in conjunction with other coagulants is assessed by analysing and comparing these water quality indicators before and after the application of the treatment. The secondary

Materials and Tools

Aloe vera and PAC were used as coagulants. Sulfuric acid, oxalic acid, and sodium oxalate were employed as reagents for measuring organic matter (SNI 06-6989.22-2004). For iron measurement, hydrochloric acid, hydroxylamine solution, ammonium acetate buffer solution, sodium acetate solution, phenanthroline solution, ammonium iron sulfate, and acetic acid were used (APHA, AWWA, and WEF. 2012). Potassium permanganate was utilized as a reagent for both iron and organic matter measurement (APHA, AWWA, and WEF. 2012).

A spectrophotometer was used to measure absorbance for iron and ammonia concentration, while a hotplate was used to heat water samples for organic matter measurement. Various types of glassware, including burette, Erlenmeyer flask, volumetric flasks, and beaker glass, were used for measuring, diluting, and holding water samples. A jar test apparatus for coagulation and flocculation processes was also utilized.

The water samples for the organic matter parameter were used in the original river water samples. The water samples for iron and ammonia were made by adding the iron or ammonia standard solution to the river water samples until a certain concentration was needed in the research.

Research Limitation

The study was limited to

a. A laboratory scale experiment.
b. Primarily focus on the water chemical quality parameters: organic matter, ammonia, and iron
c. Raw water samples with turbidity levels ranging from 30 to 60 NTU were used as the basis for experimentation, representing a typical condition
d. The findings of this study may be limited in their applicability and may require validation through additional research in diverse geographical and environmental contexts.
e. This study does not consider the economic feasibility, which is recognized as an aspect of practical applications.

3. Results and Discussion

The research experiments activities were done on the laboratory scale by the variation of experiments as follows in **Table 2.**

Table 2. Research experiments activities

Parameter	Raw water samples	Treatment	Treated Water
Organic matter	Raw Water	Jar Test with PAC 26 mg/L	Organic matter analysis
	Organic matter analysis	Jar tes with (PAC 17 mg/L+ *Aloe* vera 180 mg/L)	
Iron	Raw Water + Fe	Jar Test with PAC 26 mg/L	iron analysis
	iron analysis	Jar tes with (PAC 17 mg/L+ *Aloe* vera 180 mg/L)	
Ammonia	Raw Water	Jar Test with PAC 26 mg/L	ammonia analysis
	ammonia analysis	Jar tes with (PAC 17 mg/L+ *Aloe* vera 180 mg/L)	

The experiments were done by two replications with the different river water samples on different dates. In each experiment, measurements of each parameter including organic matter, iron, and ammonia, were done by 2 – 3 replications.

Combination of Aloe vera gel with PAC effect to Organic Matter Concentration

Table 3 shows the raw data of organic matter concentration collected from 2 replicants' experimental laboratory as the primary data. The organic matter concentration analysis was done for the original sample, after treatment with 26 mg/L PAC only and after treatment with a combination of 17 mg/L of PAC with an additional 180 mg/L of *Aloe vera*.

Table 3. Organic matter concentration data

Experiment	Organic matter (mg/l)		
	Raw water	After treatment withPAC	After treatment withPAC + Aloe Vera
1	33.24	30.26	34.46
	33.72	31.00	35.95
Average	**33.48**	**30.63**	**35.21**
2	31.71	30.75	33.97
	33.23	31.74	34.96
Average	**32.47**	**31.25**	**34.47**

Figure 3 shows the average values for organic matter in the two experiments revealing distinct trends when using different treatment methods. In both experiments, the use of PAC alone resulted in a significant reduction in organic matter. Specifically, the average values of organic matter decreased from 33.48 mg/L to 30.63 mg/L in the first experiment and from 32.47 mg/L to 31.25 mg/L in the second experiment. This reduction can be attributed to the well-known adsorptive properties of PAC, which effectively remove organic contaminants from water due to its large surface area and porous structure.

Conversely, when PAC was combined with *Aloe vera*, an increase in the organic matter content was observed. The average values rose to 35.21 mg/L in the first experiment and 34.47 mg/L in the second experiment. This increase is likely due to the organic compounds present in *Aloe vera*, such as polysaccharides, glycoproteins, and enzymes [12]. These compounds contribute additional organic load to the water, which the PAC alone cannot fully adsorb, resulting in a net increase in the measured organic matter.

In summary, while PAC alone effectively reduces organic matter through adsorption, the combination of PAC and *Aloe vera* leads to an increase in organic matter. This outcome is due to the introduction of organic compounds from *Aloe vera*, which surpasses the PAC adsorptive capacity.

The ANOVA statistical analysis of organic matter concentration in both experiments of the original water sample, after treatment with PAC and after treatment PAC and *Aloe vera* generated a P-value of 1.75×10^{-7} which is < 0.05. It means there is a significant difference between them

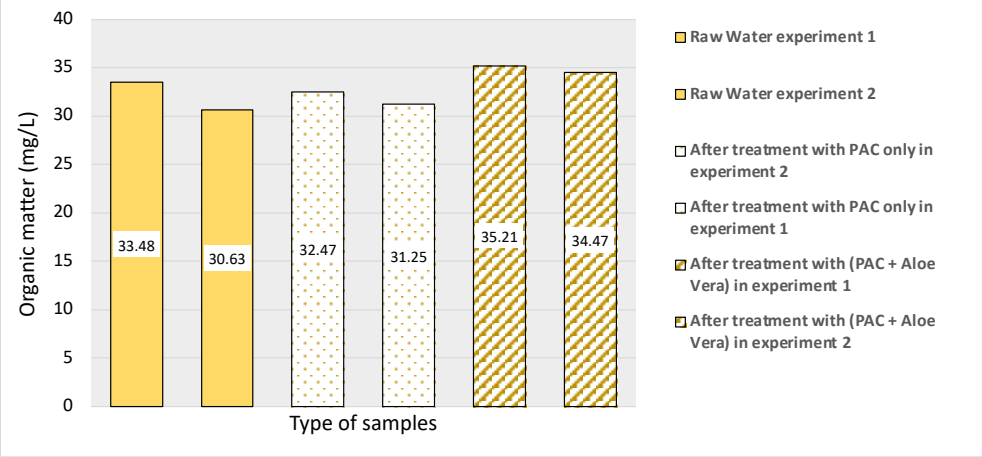

Fig. 3: Organic matter concentration before and after treatment

Combination of Aloe vera with PAC effect on Ammonia Concentration

Table 4 shows the raw data of ammonia concentration collected from 2 replicants' experimental laboratory as the primary data. The ammonia concentration analysis was done for the original sample, after treatment with 26 mg/L PAC only and after treatment with a combination of 17 mg/L of PAC with an additional 180 mg/L of *Aloe vera*.

Table 4. Ammonia concentration data

Experiment	Ammonia (NH3) (mg/L)		
	Raw water	After treatment withPAC	After treatment withPAC + Aloe Vera
1	0.49	0.23	0.21
	0.49	0.23	0.21
	0.49	0.23	0.21
Average	**0.49**	**0.23**	**0.21**
2	0.38	0.23	0.21
	0.38	0.23	0.21
	0.38	0.23	0.21
Average	**0.38**	**0.23**	**0.21**

Figure 4 shows the comparison of ammonia concentration in raw water, treated water with a combination of *Aloe vera* and PAC, and treated water with PAC only across two experiments. In both, experiments, the raw water shows the highest concentration, with the first experiment at 0.49 mg/L, and the second experiment at 0.38 mg/L. The treatment methods significantly reduce ammonia levels. The treated water using the combination of *Aloe vera* and PAC shows a reduction to 0.213 mg/L in the first experiment and 0.211 mg/L in the second experiment. In comparison, the treated water using PAC only shows slightly higher ammonia levels at 0.236 mg/L for the first experiment, and 0.235 mg/L for the second experiment. Overall, both treatment methods effectively lower the ammonia concentration, with the combination of *Aloe vera* and PAC providing a slightly better reduction than using PAC only. Previous research reported that the application of 3% of *Aloe* sp. Gel combined with 3% water glass (sodium metasilicate) in wastewater samples can remove NH4-N by 89% [13]. Compared to this research that used 180 mg/L or 0.018% *Aloe vera* gel applying 3% of *Aloe vera* gel was a much higher concentration.

The ANOVA statistical analysis of organic matter concentration in both experiments of the original water sample, after treatment with PAC and after treatment PAC and *Aloe vera* generate a P-value which is $3.04 \times 10^{-14} < 0.05$. It means there is a significant difference between them.

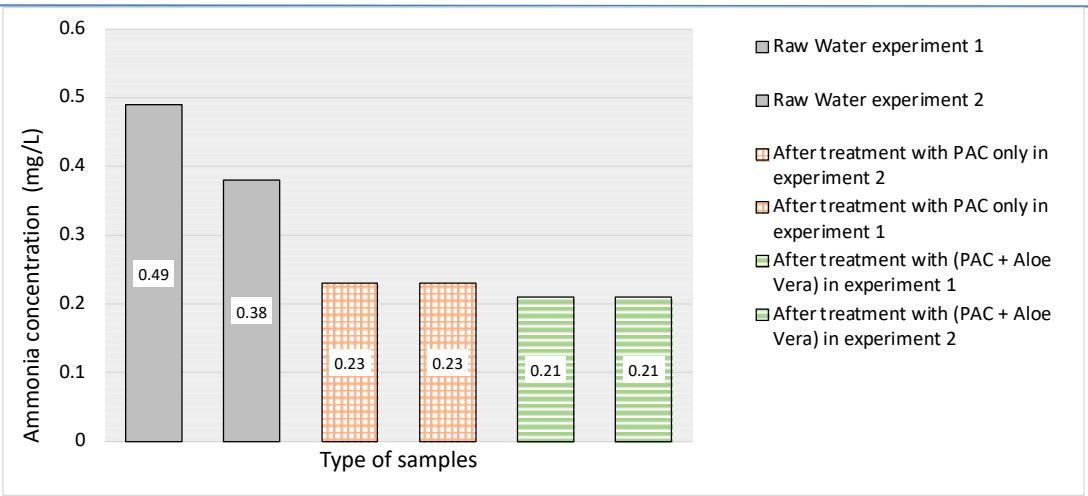

Fig.4: Ammonia (NH_3) concentration before and after treatment

Combination of Aloe vera with PAC effect on Iron Concentration

Table 5 shows the raw data of iron concentration collected from 2 replicants' experimental laboratory as the primary data. The iron concentration analysis was done for the original sample, after treatment with 26 mg/L PAC only and after treatment with a combination of 17 mg/L of PAC with an additional 180 mg/L of *Aloe vera*.

Table 5. Raw data on iron concentration

Experiment	Iron (Fe) (mg/l)		
	Raw water	After treatment withPAC	After treatment withPAC + Aloe Vera
1	5.04	2.61	1.64
	5.80	3.05	2.04
	5.42	2.83	1.84
Average	**5.42**	**2.83**	**1.84**
2	7.10	2.73	1.52
	5.94	3.15	2.28
	6.52	2.94	1.90
Average	**6.52**	**2.94**	**1.90**

Figure 5 compares the iron concentration in three types of water samples across two experiments. In experiment 1, the raw water has an iron concentration of 5.42 mg/L. After treatment with the combination of *Aloe vera* and PAC, the iron concentration is reduced to 1.84 mg/L, while treatment with PAC only reduces to 2.83 mg/L. In experiment 2, the raw water has a higher iron concentration of 6.52 mg/L. The combination treatment reduces this to 1.90 mg/L, and the PAC-only treatment reduces to 2.94 mg/L.
Aloe vera in powder form has been reported [14] can reduce heavy metal Pb and reduce heavy metal Zinc and Sodium [15] by the adsorption process. Application *Aloe* gel with PAC liquid combination in this research showed a similar reduction in heavy metal iron.

The ANOVA statistical analysis of organic matter concentration in both experiments of the original water sample, after treatment with PAC and after treatment PAC and *Aloe vera* generated a P-value of 9.19×10^{-12} which is < 0.05. It means there is a significant difference between them.

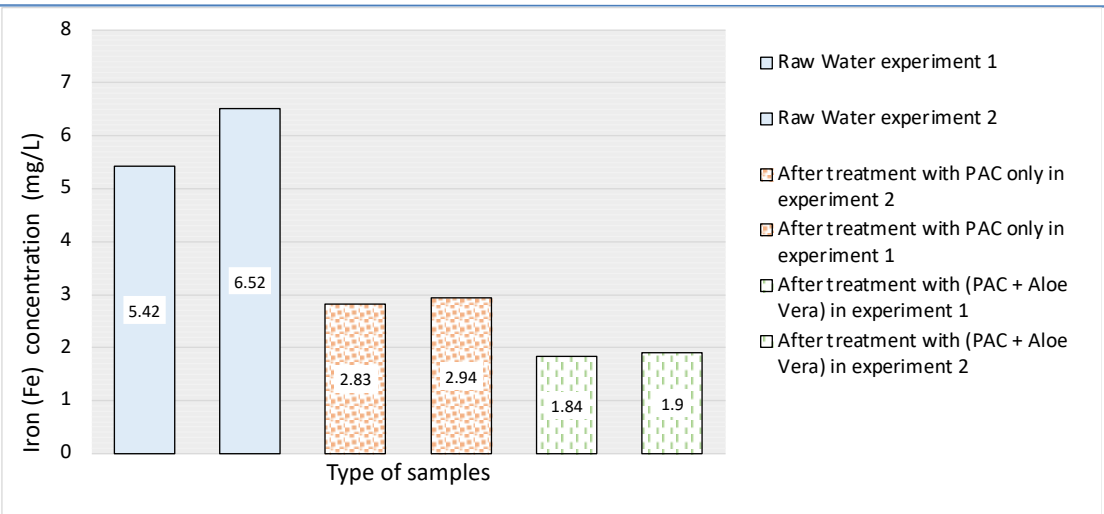

Fig.5: Iron (Fe) concentration before and after treatment

4. Conclusion

The experimental results showed that the use of a combination of PAC and *Aloe vera* compared to the use of PAC alone resulted in a better reduction in iron levels, and the practically same reduction in ammonia, but increased the levels of organic matter in the water samples.

5. Acknowledgment

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6. Abbreviations

PAC	Poly Aluminum Chloride
%	Percentage
NOM	Natural Organic Materials
ANOVA	Analysis of Varian
NTU	Nephelometric Turbidity Unit
OMP	Outer membrane protein

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