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The Potential of Aloe Vera Application as Coagulant in Reduce PAC Consumption in Drinking Water Treatment Process

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Abstract
This study investigates the use of aloe vera as an alternative coagulant to PAC in the treatment of the Tarum Barat Canal, which is vital to local communities but faces declining water quality due to upstream land use changes and human activities. The aim is to assess the potential of aloe vera to reduce the consumption of PAC in drinking water treatment and to determine the optimal dosage for effective turbidity reduction and pH regulation. Primary data were collected through laboratory experiments evaluating key water indicators, while secondary data from PT. X provided additional insight into the canal's water quality from January to July 2023. The results show that PAC alone achieves a turbidity removal efficiency of 96.76%, while the combination of Aloe Vera and PAC achieves 95.03%. Both treatments maintain pH levels within the safe range set by the Indonesian Ministry of Health. The optimum dosage was found to be 17 ppm PAC with 180 ppm Aloe Vera, which meets drinking water standards and reduces PAC use by 56.25%.
Keywords: *aloe vera, drinking water, PAC, pH, tarum barat canal, turbidity*

Abstrak
Penelitian ini mengeskplorasi penggunaan lidah buaya sebagai koagulan alternatif untuk PAC dalam pengolahan air di Kanal Tarum Barat, yang sangat penting bagi masyarakat lokal tetapi menghadapi penurunan kualitas air akibat perubahan penggunaan lahan di hulu dan aktivitas manusia. Tujuannya adalah untuk menilai potensi lidah bauat dalam mengurangi konsumsi PAC dalam pengolahan air minum dan menentukan dosis optimal untuk mengurangi kekeruhan secara efektif serta mengatur pH. Data primer dikumpulkan melalui eksperimen laboratorium yang mengevaluasi indikator utama kualitas air, sementara data sekunder dari PT.X memberikan wawasan tambahan tentang kualitas air di kanal Tarum Barat dari Januari hingga Juli 2023. Hasilnya menunjukkan bahwa PAC saja mencapai efisiensi pengurangan kekeruhan sebesar 96,76%, sedangkan kombinasi lidah buaya dan PAC mencapai 95,03%. Kedua perlakuan menjaga tingkat pH dalam kisaran aman yang ditetapkan oleh Kementrian Kesehatan Indoneisa. Dosis optimal ditentukan sebesar 17 ppm PAC dengan 180 ppm lidah buaya, yang memenuhi standar air minum dan mengurangi penggunaan PAC sebesar 56,25%.
Kata Kunci: *air minum, kanal tarum barat, kekeruhan, lidah buaya, pH*

1. Introduction

Freshwater, which makes up only 0.02% of the water on Earth, is under threat from climate change, urbanization, and increased demand from a growing global population. Yearly, about 45.500 km^3 of water moves from rivers to oceans, a cycle influenced by regional rainfall and evaporation [1]. Developing countries face additional challenges due to inadequate waste management and sanitation, affecting water quality and accessibility. Contamination from pathogens and pollutants further degrades water quality, posing significant health risks despite international efforts to improve water security [2],[3].

River, as natural sources of freshwater, flow into oceans, lakes, or other rivers are vital for everyday use by many community [4]. Indonesia Government Regulation No.38 of 2011 defines a river as a natural or artificial channel that caries water from its source to its mouth, flanked by demarcation lines on both sides [5]. A key example is the West Tarum Canal (WTC) in West Java, which spans 68.8 kilometer [6]. To preserve environmental health standards, the Regulation of Minister of Health Republic of Indonesia No.2 of 2023 stipulates the monitoring of water for physical parameters like temperature, Total Dissolves Solids (TDS), turbidity, color, and odor, as well as chemical aspects including pH and various metal and mineral concentrations [7]. These regulations highlight the importance of maintaining water quality in vital waterways like WTC, reflecting Indonesia's commitment to managing its crucial water resources effectively.

The water quality of the WTC in Indonesia has been adversely affected due to changes in land use

upstream and various local river inputs that degrade its raw water quality [8]. These changes are largely attributed to the modification of land use patterns around the WTC and an increase in human activities. The area around the WTC and an increase in human activities. The area around the WTC is a hub of diverse community activities that range from agriculture and industrial operations to everyday domestic tasks such as bathing, laundry and sanitation [8]. These activities contribute to the deterioration of water quality in the canal. In response to these challenges, specific water treatment methods are employed. One such methods is coagulation-flocculation, which is effective in removing a range of impurities, including colloids, suspended particles, and metal ions from the water [9]. This treatment process is vital for purifying both surface and groundwater, ensuring that it is safe for human consumption. The implementation of such water treatment techniques is critical in maintaining the health standards of water bodies like the WTC, reflecting ongoing efforts to manage and improve water quality in the face of environmental and anthropogenic challenges.

Poly aluminum chloride (PAC) is commonly used as a chemical agent in the coagulation-flocculation process. The material safety data sheet for PAC indicates that it is used in water treatment, it has potential to cause skin and eye irritation due to its mildly acidic with pH of 2-4, which is corrosive [10]. The utilization of PAC in water treatment has proven to be efficient in the process of coagulation. However, it has been observed that this practice has adverse effects on the microbial communities present in river sediments. It leads to a decrease in the diversity of prokaryotic organisms and disrupts the equilibrium of microbial flora. This disturbance to the microbial community might impact crucial ecological processes and the quality of water. Therefore, the environmental consequences of using PAC emphasize the importance of adopting a well-rounded strategy in drinking water treatment methods, taking into account both the effectiveness of purification and the ecological sustainability [11]. Aloe Vera, among other natural coagulants, is being evaluated for its ability to decrease treatment expenses and mitigate the ecological consequences associated with synthetic coagulants, which frequently exhibit detrimental side effects. Having characteristics akin to those of cactus plants. Aloe vera is renowned for its efficacy in water purification, offering an environmentally beneficial choice. Aloe vera contains mucilage that rich in pectic polysaccharides, specifically poly galacturonic acids, which have been proven to decrease the level of cloudiness in water [12] [13].

Aloe vera has mucilage that contains Poly galacturonic acid, which has been proven to decrease the level of cloudiness in water[14]. Poly galacturonic acid functions as a coagulant by attracting and binding particles together through a process called adsorption and bridging. This results in the creation of flocs in the water, where particles that are not directly in contact with each other are brought together by the Poly galacturonic acid compounds. The inclusion of cationic carboxyl (COOH) groups in aloe vera facilitates the attachment of suspended and colloidal particles, resulting in an enhancement in water quality. The property of aloe vera improves the clumping together of these particles, making the purifying process easier [15].

Aloe vera was chosen as a coagulant due to its ease of culture and its availability for large-scale growth. Aloe vera is a plant that thrives in regions with somewhat long dry seasons and is therefore a species that efficiently uses water [16]. Aloe Vera is a ubiquitous plant that thrives organically in Indonesia. Pontianak, located in West Kalimantan, is the most productive region for Aloe Vera cultivation. In 2017, it generated a staggering 18.4 million kg of Aloe Vera [17]. East Java is a major producer of Aloe Vera in Indonesia, with a production of about 495 kilos in 2021 and around 388 kilograms in 2022 [18]. In addition to East Java and West Kalimantan, Batam City also made a significant contribution to Aloe Vera production, producing a minimum of 400 kg per year in 2022 [19]. In 2021, West Java yielded a total of 130.279 kg of Aloe Vera [20].

2. Material and Methods

Research Framework

The research framework outline in **Fig 1** presents a structured approach to evaluating the potential of aloe vera as a coagulant to reduce the use of PAC in drinking water treatment. It begins by identifying the global water crisis and the negative impacts of PAC, highlighting aloe vera as an alternative. A comprehensive literature review consolidates existing knowledge on these issues and the coagulating properties of aloe vera. Secondary data on water quality standards and regulations is collected to provide context for the experimental investigation.

The methodology transition to an empirical phase, where detailed laboratory experiments test the coagulation efficacy of aloe vera, both alone and in combination with PAC. These results are rigorously analyzed to determine the effectiveness of aloe vera as coagulant. The research concludes with a critical

discussion of the findings, validating the hypothesis that aloe vera can reduce PAC usage in water treatment. The study reflects on the implications of these findings and suggests directions for future research in this promising area.

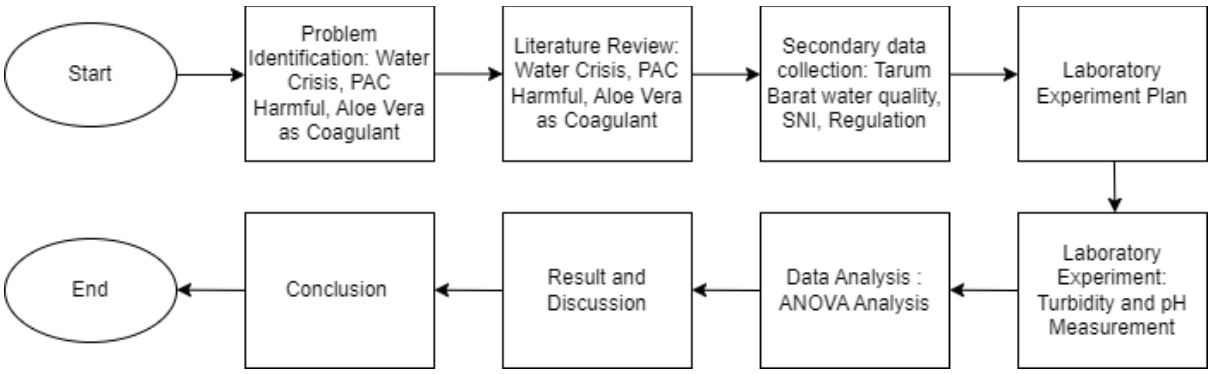

Fig 1. Research Framework

Primary Data

This study uses primary data directly collected by the author through laboratory experiments. Turbidity and pH levels in water samples from West Tarum Canal are measured. The experiments are conducted on six different occasions to assess Aloe Vera's potential as a coagulant for drinking water. The effectiveness of this treatment is evaluated by comparing water quality parameters before and after treatment

Secondary Data

Additionally, this study utilizes secondary data from PT. X to understand the water quality of the West Tarum Canal. Parameter such as turbidity and pH are examined, covering data from January to July 2023.

Water Sampling

Water samples for this study were systematically collected from PT.X beginning on January 24, 2024, with subsequent samples on January 26, February 1, February 8. The collection followed the SNI 6989.59:2008 standard for random sampling, ensuring an unbiased representation of water quality fluctuations. Samples were promptly analyzed in a laboratory, including jar tests to evaluate the coagulation capabilities of aloe vera and PAC, focusing on turbidity levels between 30-60 NTU. Adhering to these standards ensures the credibility and representativeness of the data regarding the effectiveness of the water treatment methods.

Table 1. Drinking Water Quality Standards

No	Parameter	Method	Reference	Quality standard	Unit
1	Turbidity	Nephelometer	APHA, AWWA and WEF. 2012, Standard Methods For The Examination of Water and Wastewater	< 3	NTU
2	pH	Digital pH meter	APHA, AWWA and WEF. 2012, Standard Methods For The Examination of Water and Wastewater,	6.5-8.5	

Source: Peraturan Menteri Kesehatan No. 2 (2023)

This regulation provides stringent guidelines to ensure the safety and health standards of water for consumption and other uses. To assess the water quality against these standards, the research employs specific methodologies detailed in **Table 1** [7]. These methods are systematically applied to measure each parameter accurately, ensuring that the research findings are reliable and in accordance with national health regulations.

Aloe Vera Liquid Preparation (20% and 33.3%)

Aloe vera leaves sourced from South Tangerang were prepared for this research using a meticulous process to ensure a pure, particle-free solution. The leaves were thoroughly cleansed to remove impurities, and the gel was separated from the tough outer shell. The gel was cut into smaller pieces and blended into a liquid form. For the experimental solution, 90 mL of blended aloe vera gel was mixed with 180 mL of distilled water and another mixture was made by combining 20 ml of blended aloe vera gel with 80 ml of distilled water. The mixtures were stirred well to ensure uniformity and then filtered to remove any solid particles. This process ensured that the aloe vera solution used in the experiments was free from impurities and solid particles.

PAC Working Solution (0.01%)

The preparation of PAC solution for water treatment experiments involves the following steps. First, add 0.5 ml of 10% PAC to a volumetric flask. Then, dilute with 500 ml of distilled water. Vigorously shake the flask 30 times to ensure uniform distribution of the PAC throughout the solution. And result PAC working solution with 0.01% concentration.

Jar Test Experiments

Jar test is a method used to replicate a full-scale water treatment process, providing operators with insight into how a treatment chemical will behave with a specific type of raw water [21]. The jar test is crucial for optimizing treatment processes, minimizing chemical usage, customizing treatments for specific water sources, and ensuring regulatory compliance for drinking water quality [22]. To conduct the test, place 1000 mL of raw water into 1000 mL glass beakers and add the coagulants. Perform rapid mixing at 160 RPM for 3 minutes to thoroughly mix the coagulants with the water, followed by slow mixing at 30 RPM 20 minutes. Then, observe the effectiveness of floc formation and settling over a 30- minute period, as shown in **Table 2** [23].

Table 2. Jar Test Speed

Variable	Speed (RPM)	Time (minute)
Rapid Mixing	160	3
Slow Mixing	30	20
Sedimentation	-	30

Source: A. Benalia Et Al. (2021)

3. Results and Discussion

Table 3, shown evaluates the efficacy of different coagulants for turbidity removal, starting with aloe vera liquid at a 33.3% concentration. The initial turbidity was 40.10 NTU. Thus 33.3% concentration is achieved by diluting 90 mL of aloe vera liquid at 1000000 ppm to a 270 mL of distilled water, resulting in 333,333.3 ppm or 33.3% (v/v). As the dosage of aloe vera liquid increased from 33.3 ppm to 99.9 ppm, a decrease in removal efficiency was observed, indicating aninverse relationship between dosage and effectiveness.

In comparison, PAC showed a positive dosage-response correlation. Starting with a low dosage of 2.5 ppm and increasing to 26 ppm, turbidity reduction peaked at 98.81%, indicating an optimal concentration for maximum clarity. To understand PAC concentration, consider its dilution process; 0.5 mL of a 100,000 ppm PAC solution is diluted with 500 mL of distilled water. This results in a concentration of 100 ppm, which corresponds to 0.01% (v/v) of the total volume, indicating the PAC solution used was 0.01% of the total volume.

Table 3. Comparison of Turbidity value in each treatment

Type of Coagulant	Sampling Date	Dosage (ppm)	Initial Turbidity	Final Turbidity	Removal efficiency
Aloe Vera Liquid 33.3%	**20-Jan-24**	33.3	40.10	20.19	49.65
		66.6	40.10	21.56	46.23
		99.9	40.10	23.35	41.77
PAC (0.01%)	**26-Jan-24**	2.5	32.00	10.19	68.17
		5	32.00	5.83	81.80
		10	32.00	2.35	92.67
		15	32.00	1.26	96.08
		25	32.00	0.69	97.84
		26	32.00	0.38	98.81
		27	32.00	0.67	97.91
		28	32.00	0.50	98.45
		29	32.00	0.55	98.28
		30	32.00	0.56	98.27
Aloe Vera Liquid 20%	**1-Feb-24**	60	47.10	19.6	58.39
		120	47.10	19.745	58.08
		180	47.10	19.45	58.70
		240	47.10	19.6	58.39

In comparison, PAC showed a positive dosage-response correlation. Starting with a low dosage of 2.5 ppm and increasing to 26 ppm, turbidity reduction peaked at 98.81%, indicating an optimal concentration for maximum clarity. To understand PAC concentration, consider its dilution process; 0.5 mL of a 100,000 ppm PAC solution is diluted with 500 mL of distilled water. This results in a concentration of 100 ppm, which corresponds to 0.01% (v/v) of the total volume, indicating the PAC solution used was 0.01% of the total volume.

Further trials with 20% aloe vera liquid identified 180 ppm as the optimal dosage, achieving a 58.70% reduction in turbidity. This 20% concentration (v/v) is derived by diluting 20 mL of aloe vera liquid at 1,000,000 with 100 mL of distilled water, resulting in 200,000 ppm or 20% (v/v). This measn that in the final solution, 20 % of the volume is aloe vera liquid. **Table 3** suggests optimal dosages for both coagulants, 180 ppm of aloe vera liquid (20%), to achieve maximum clarity. According to the turbidity standards set by the Ministry of Health Republic of Indonesia in regulation number 2 of 2023, water turbidity levels must be maintained below 3 NTU. However, as shown in **Table 3**, aloe vera alone does not meet these criteria, whereas PAC successfully adheres to the standards. To optimize PAC usage and explore synergistic effects, experiments were conducted combining PAC with aloe vera. This combined approach potentially reduces the amount of PAC needed by supplementing it with aloe vera.

Table.3 indicates that the optimal dosage of aloe vera for turbidity reduction is 180 ppm, achieving a removal efficiency of 58.70%. Based on these findings, this dosage was selected to be used alongside the optimal dosage of PAC. The objective of combining these dosages is to reduce the reliance on PAC as the sole coagulant, utilizing aloe vera to enhance overall water treatment efficacy. This strategy aims to meet stringent health standards while promoting more sustainable and cost-effective water treatment practices. The research aims to validate the effectiveness of this coagulant combination, assessing its ability to comply with national water quality regulations while optimizing chemicals usage.

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Table 4. Comparison of % Removal of Turbidity

Sampling Date	Aloe Vera Dosage (ppm)	PAC Dosage (ppm)	Initial Turbidity	Final Turbidity	Removal Efficiency
1-Feb-24	180	22	47.10	1.25	97.36
	180	21	47.10	1.24	97.38
	180	20	47.10	1.87	96.03
	180	19	47.10	1.75	96.28
	180	18	47.10	2.07	95.62
	180	17	47.10	2.58	94.52
	180	16	47.10	3.17	93.28
	180	12	47.10	3.29	93.03
	180	8	47.10	7.34	84.43

According to data from **Table 4**, the synergistic use of aloe vera and PAC meets the drinking water standards set by Ministry of Health Republic of Indonesia. The optimal dosage was determined to be 17 ppm of PAC combined with 180 ppm of aloe vera, achieving a significant turbidity reduction 94.52%, with final turbidity in 2.58 NTU. This combination of aloe vera and PAC not only complies with regulatory standards but also optimizes chemical usage, enhancing the sustainability of water treatment practices.

Fig 2 compares turbidity reduction using 26 ppm of PAC alone and combination of 180 ppm of aloe vera with 17 ppm of PAC. These results demonstrate that the aloe vera and PAC combination meets the drinking water quality standard, requiring turbidity levels below 3 NTU. This combination effectively reduces the required PAC dosage from 26 ppm to 17 ppm, a 56.25% reduction. This reduction promotes a more sustainable and eco-friendly water treatment process with lower environmental impact. The reduction percentage is calculated by comparing the difference between the initial PAC dosage and the combined aloe vera and PAC dosage, then dividing by the initial PAC dosage and multiplying by 100.

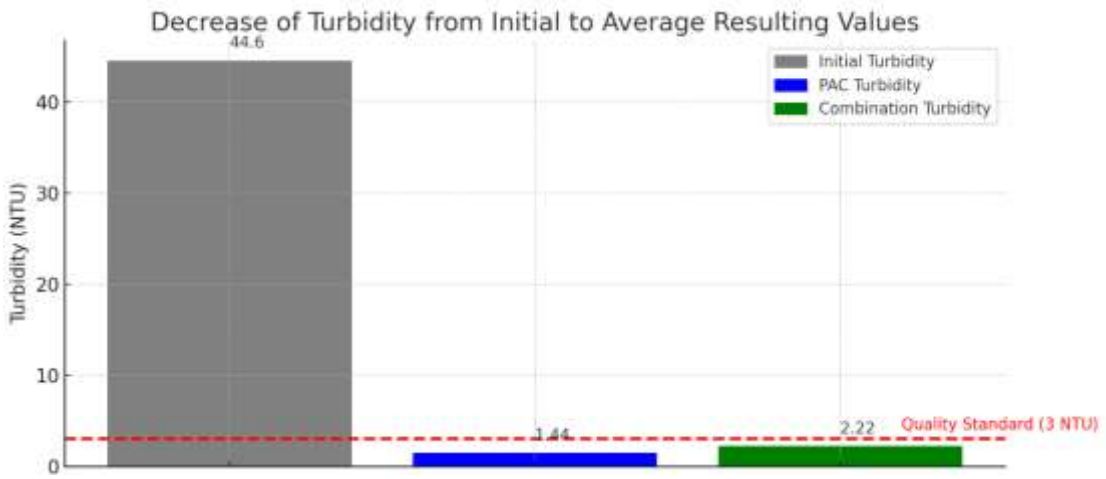

Fig 2. Comparison of Turbidity in each Treatment

Fig 3 shows the pH levels and turbidity removal percentages for two coagulants. The initial pH of the water is 7.74. After treatment with PAC alone, the average pH rises slightly to 7.87. The combination of aloe vera and PAC results in an average pH of 7.81, closer to the initial value. This indicates that the combination treatment has a less significant impact on the water's pH balance.

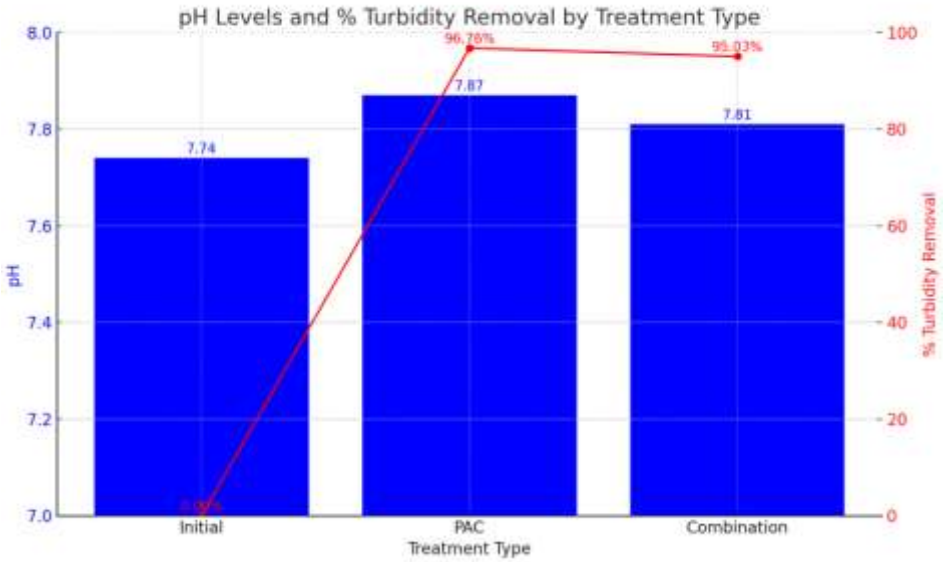

Fig 3. pH levels and percentage of turbidity removal

PAC achieves a very high turbidity removal efficiency with an average of 97.76%. The combination of aloe vera and PAC shows a slightly lower efficiency at 95.03%, but still remain highly effective. According to the Regulation of the Ministry Health Republic of Indonesia Number 2/2023, the pH level of drinking water must fall within a safe range. Both treatments results in pH levels within this range, ensuring compliance with the standards. The combination coagulant maintains a pH closer to neutral compared to

4. Conclusion

This research found that using aloe vera liquid can significantly reduce the amount of PAC needed in the drinking water treatment process. The study revealed that combining 17 ppm of PAC with 180 ppm of aloe vera liquid achieved a turbidity reduction of 95.03%, resulting in final turbidity levels of 2.58 NTU and pH of 7.81. This combination not only meets the drinking water standards set by the Ministry of Health Republic of Indonesia but also demonstrate a 56.25% reduction in PAC consumption. This indicates that aloe vera liquid can optimize chemical usage and enhance the sustainability of water treatment practices. The combination of aloe vera and PAC proves effective in reducing turbidity and regulating pH levels, showcasing the potential for more sustainable and efficient water treatment practices by reducing reliance on PAC alone.

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6. Abbreviations

NTU	Nephelometric Turbidity Unit
%	Percentage
PAC	Poly Aluminum Chloride

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