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EFFECTIVENESS OF POLY ALUMINUM CHLORIDE COAGULANT ON THE PERFORMANCE OF IPAM BADAKSINGA, BANDUNG CITY

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ABSTRACT

The Badaksinga Drinking Water Processing Installation is an installation owned by Perumda Tirtawening Drinking Water, Bandung City, has 2 of these installations, the first of which is a design from Degremont - France, built around 1954 with a capacity of 1000 liters/second. The second installation is an IWACO-Dutch design with a flow rate of 800 liters/second. The raw water for the two installations comes from the Cisangkuy River and the Cikapundung River. To purify the raw water, PAC (Poly Aluminum Chloride) is used as a coagulant which is a complex inorganic compound with a clear to yellowish color. The coagulant addition process must be carried out efficiently because this coagulation process is a chemical process that requires a large amount of money for the water treatment process apart from chlorination. Excessive addition of coagulant doses will cause the cost of using coagulant chemicals to swell so that it will have an impact on overall operational costs. The purpose of this study was to determine the effectiveness of using PAC in reducing turbidity, in the form of the optimum dose of coagulant, turbidity and pH. The method used is the Jar Test which is a tool to test the ability of coagulants to determine the optimum dose in a water treatment process. From the samples, the raw water turbidity varied from 17.1 to 281 NTU, fluctuating due to geographical location and environmental conditions around each and the degree of acidity or an average pH of 7.13. After the Jar Test was carried out, the optimum dose was produced at a coagulant concentration of 30 mg/l resulting in turbidity in the range of 1.1 to 5.0 NTU and an average turbidity reduction efficiency of 94.5%, the pH of raw water, after coagulation and flocculation with the Jar Test simulation tool, there was a decrease of 4.1% to an average of 6.99. This result is in accordance with Minister of Health Regulation No 492/MENKES/PER/10/2010 April 19 2020, namely turbidity of no more than 5 NTU and a pH of 6.5 – 8.5

KEYWORDS *Optimum dose, Poly Aluminum Chloride, turbidity, raw water*

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INTRODUCTION

The Regional Drinking Water Company Tirtawening Bandung City currently serves 69.30% of the population of Bandung City from the national target of 80%. Some of the problems faced by PDAM Tirtawening include limited raw water supply, high leakage rates, clean water supply systems that have not been integrated and limited capacity and competence of human resources for clean water service providers. Then a Drinking Water Supply System or SPAM was formed which functioned to produce hingga water to customers.

IPAM Badaksinga in Bandung City has 2 installations, the first of which is a design from Degremont - France, built around 1954 with a capacity of 1000 liters / second. The 2nd installation is designed by IWACO-Netherlands with a discharge of 800 liters / second. The raw water for the two installations comes from the Cisangkuy River and the Cikapundung River. 2 Transmission pipes with a diameter of 850 mm drain raw water along 32 km from the Cisangkuy River, while raw water from the Cikapun dung Riveris flowed through a transmission pipe with a diameter (800-900) mm.

The intake for the Cisangkuy Cikapundung River is in the Dago Crooked and Sabuga areas. The intake is a building to capture raw water and drain it through transmission pipes, consisting of intake doors, screen bars, collection tanks and outlet pipes. From Sabuga the outlet pipe with a diameter of 600 mm has a maximum discharge capacity of 250 l / second while from Dago Bent a diameter of 800 mm is used for mangrove water intake with a maximum capacityof 600 l / second. For Cisangkuy intake, the maximum capacity is 1600 l / second, which then drains the water into a presedimentation basin in the Cikalong area. Dago Crooked and Sabuga intakes directly drain their raw water to IPAM Badak Singa

IPAM Badak Singa has water treatment units which include 2 presedimentation tubs, 8 coagulation units, 4 accelerators, 4 flocculation units, 4 sedimentation units, 30 filter units, 1 disinfection unit and 1 reservoir unit. The distribution service systemto customers is divided into 3 Service Areas, namely; West Bandung, North Bandung and East Bandung areas. Its distribution through pipelines by means of gravity to the service area. The Badaksinga IPA is equipped with a *Control Display Control Panel* (CDCP room) which functions to control the entire water treatment, from the transmission pipe to the effluent control tub. The room is equipped with an online process monitoring tool. One of its functions is tofind out the amount of raw water and clean water produced.

The use of PAC (Poly Aluminum Chloride) coagulants is highly dependent depending on the characteristics of the raw water, causing the results to vary greatly so that information is needed about the quality of the raw water source, as well as research in determining the optimal type and concentration of coagulants to treat the river water so that it can be further processed into qualified drinking water. For this reason, this study was conducted to obtain information on the optimum dose of PAC coagulants by conducting coagulation experiments on raw water originating from the Cisangkuy River and Cikapundung River using a jar test tool so that water quality was obtained that met the quality standards according to the Indonesian Health Regulation No.429 / MENKES / PER / IV / 2010.

The technology applied starts from taking raw water, treating water to become clean water which is very dependent on the quality of the source, then through the distribution system is flowed through piping to the service area. Water Treatment is carried out on water that basically does not ordoes not meet the applicable drinking / clean water quality standards, so that elements that do not meet the standards need to be removed or reduced. This is done by treating the water. In general, the water contained in the area that can be consumed by humans, is sourced from rainwater, surface water and groundwater. Of the three water source waters, what can be directly consumed by humans is rainwater and groundwater with certain criteria. As for surface water, generally cannot be consumed directly because of several things, including causing health problems.

Water Treatment to produce drinking water is an effort to obtain drinking water with quality in accordance withapplicable standards. The method can be in the form of complete processing or partial processing. Complete processing includes physical, chemical and biological processing. For planning installation package units with a capacity between 1 to 50 l / second, the Indonesian Rice onal Standardstipulates in SNI 6774: 2008. The content of this SNI consists of planning criteria, raw water, installation capacity, operating units and others. The operating and process units on this installation package consist of coagulation, si floccula, flotation, sedimentation, filtration and disinfection. Technical requirements for raw water that can be treated by a Drinking Water Treatment Plant (IPAM), include: Turbidity, maximum 600 NTU or 400 mg / L SiO2 ; The original color content (as apparent colour) did notexceed 100 Pt Co and the color temporarily followed the turbidity of the raw water; Other elements meet the raw water standard requirements of Government Regulation No. 82 of 2001 concerning Water Quality Management and Water Pollution Control; In the event that the river water area has a color, iron and or organic matter content exceeding the aforementioned requirements but low turbidity (< 50NTU) then the IPA system of Dissoved Air Flotation or other systems that can be accounted for is used.

Coagulation andFlocation

Coagulation and flocculation in a water treatment system are the most important parts. Characterized by the formation of flocs that can precipitate indicating the success of a chemical separation of solids. In the process of coagulation andfloculation, what occurs is the turning of coagulants which are chemicals and the stirring of these chemicals with raw water.

The approach to evaluating stirring and designing the unit has been developed by T.R Camp (1955) who found that the fast stirring operation (flash mix) and slow stirring (slow mix) are basically stirring operations so that the required design parameters are also the same. The degree of stirring is determined by the magnitude of the power (P) given to the water during the stirring process, known as the velocity gradient (G) . the magnitude of the magnitude of G , indicates the degree of water turbulence, the greater the G the greater the turbulence of the water. In the coagulation process, mixing chemicals and splitting the stability of partikel requires a large value.

Fast stirring that is widely used is divided into Hydraulic Stirring which uses the effects of graphitation and mechanical stirring, namely stirring using equipment driven by an electrically powered motor. The stirring device is commonly called the *impeller*, based on its shape known as *a paddle*, *turbine and propeller*. The purpose of stirring in the 2 reactors is to produce collisions between particles and the number of collisions depends on: The severity of the velocity gradient(G), the grain diameter of the colliding particles and the number of the colliding particles

In the laboratory, the application of coagulation and flocculation is carried out on the Jartest tool while at the water treatment plant, it is carried out on 2 reactors, namely the coagulator and flocularator. In the coagulation process, there are several determining factors for success that are interrelated with each other, namely (Martin): The coagulant used, the optimal dose affixed and the stirring process anta ra coagulant and raw water. In the coagulation process known as *flash mixing*, mixing raw water with coagulants that occurs in seconds is a process in which negatively charged suspended particles present in water in stable conditions are made unstable. The addition of positively charged coagulants which then neutralize the negative charge through the process of destabilizing the particles.

After colloidal destabilization occurs, the next process is to drain in the next reactor known as a slow stirring reactor for the clumping or flocculation process. Stirring in the coagulation process serves to flatten the coagulant affixed with colloidal particles in raw water. At flocculation, it is planned for maximum inter-particle contact. The contact between particles is a function of the velocity gradient that can be produced by stirring both hydrolyzed and mechanical. Gradient velocity in water that causes collision/contact between particles. The greater the velocity gradient, the more particles are in contact. Besides that, the larger the velocity gradient, the smaller the floc size will be, because itbecomes a large size floc breakdown. Speed gradient, generated by arranging for water to move between bulkheads or by mechanical stirring inside the reactor.

In hydraulic floculators, the stirring can be done by flowing through thehoist horizontally or vertically which can be classified into: Baffle channel Stirring through a perforated plate and stirring with a Pulsator. In flocculations using Horizontal Baffle Channel, stirring is carried out by stirring channeling utilizing stirring energy derived from: Friction on the straight channel wall and Turbulence on the turn. The advantage is :P control over stirring is easier and capacity can be increased easily while the weakness is that it requires a large area of land.

Types of Coagulants

The types of chemicals that are often used are cationic polymer coagulants and metal salt coagulants. SNI 6774:2008, The type of coagulant used is Aluminum sulfate, $Al_2(SO4)3.14(_{H2O})$, PAC or Poly Aluminum Chloride ($Al\ _{10}(OH)15\ Cl_{15}$), Ferri Chloride (FeCl 3.6H2O) and Ferri Sulphat (Fe2(SO4)3.2H2O.

- Aluminium sulphate.

Aluminum Sulfate ($Al_3(SO4)2.14H2O$) is an example of a coagulant of a metal salt. This coagulant is a coagulant that has long been used for the coagulation process in water treatment, known by the trade name **of alum.** Aluminum sulfate produces aluminum hydroxide, $Al(OH)_3$ which hasa pH range of 5.8-8.5 for insoluble water. In conditions of high pH above 8.5, aluminum hydroxide will dissolve again in water. This will affect coagulation. Sufficient alkalinity is required for the formation and p ofthe insoluble hydroxide deposit. Colloidal and color are eliminated by adsorption on the hydrolysis of hydroxide metals. In order for coagulation to take place properly in the use of aluminum sulfate coagulants, pH control in the range of 5.8-8.5 is needed, toavoid the re-soluble occurrence of aluminum hydroxide dissolution.

The addition of Aluminum Sulfate coagulants to raw water will cause a hydrolysis reaction in water, as in reaction (1) namely the liberation of H + ions which causes a decrease in pH

$$\boldsymbol{Al_2(SO_4)_3 + 6H_2O \rightarrow 2Al(OH)_3 + 6H^+ + SO_4^{2-} \ldots\ldots (1)}$$

- Polialuminium klorida (PAC)

It is a synthetic coagulant resultingfrom poly merization of aluminum chloride. This coagulant is commonly used in drinking water treatment plants in Indonesia. The difference with Aluminum sulfate which is a coagulant of metal salts is in the level of hydrolysis in water.

Poly Aluminium Chloride (PAC) is a 3m-nlong-chain complex polymer Alm(OH)n(Cl)3m-n which is often used as a coagulant in the flocculation process in IPA. PAC consists of 3 types (SNI, 2018) namely types A, B and C with different CAS numbers. CAS number is a unique identifier number for each chemical, set by the Chemical Abstracts Service. Type A is used in the paper and water treatment industries, ranging in color from jernih (colorless) to yellowish and does not contain sulfates. PAC type B, colorless or clear, is used in the cosmetics, water treatment and other industries. It has CAS *number* 12042-91-0.For PAC type C, it is widely used for processingindustrial waste with a color range from clear to brownish color.

As in the addition of aluminium sulfate, the addition of PAC coagulants to raw water also causes a decrease in the pH of raw water, as in the following reactions:

$$\boldsymbol{Al_2(OH)_5Cl + H_2O \rightarrow 2Al(OH)_3 + H^+ \ldots.(2)}$$

From the reaction that occurs, it can be seen that there is a release of hydrogen which will cause a decrease in pH levels in water.

In its use, it has several advantages, including:

1. The corrosiveness is low because the PAC is a sulfate-free coagulant so it has low corrosiveness. This affects the security of the security and ease of the transportation and storage process.
2. The use of PAC coagulants can reduce and even eliminate corrective measures on the pH, due to a wider pH range.
3. Shorter and simpler aliphatic and clusters of hydrocarbon chains are formed due to the sulfur content with sufficient doses ofcarboxylic compounds and cyclic chains that cause it to be easily bound to form flocs

4. Can save the use of materials for neutralization due to the not too extreme decrease in pH, which ultimately has an impact on reducing the costs incurred.
5. In the process, it is simpler because it contains a special polymer with a polyelectrolite structure that can reduce the use of auxiliary materials.
6. The active group of aluminate is reinforced with polymer chains of the electrolyte group, makingthe PAC-generated fl ok denser compared to other coagulants.

Table 1
Quality Requirements of Solid Polyaluminum Chloride

No.	Test Parameters	Unit	Requirement		
			Type A	Type B	Type C
1	Aluminum oxide (Al_2O_3)	mass fraction, %	Min.27	Min.45	Min.27
2	Freedom(b/w)	mass fraction, %	0-85	80-85	45-85
3	pH Solution 1% w/v	-	3,5-5,0	3,5-5,0	3,5-5,0
4	Insoluble parts in water	mass fraction, %	0,75	0,75	0,75
5	Iron (Fe)	mg/kg	Max.300	Max.600	Max.6.000
6	Sulphate (SO4)	mass fraction, %	Max.9	-	Max.9
7	Heavy metal contamination				
7.1	Mangan (Mn)	mg/kg	Max.30	Max.30	Max.30
7.2	Cadmium (CD)	mg/kg	Max.3.0	Max.3.0	Max.3.0
7.3	Lead (Pb)	mg/kg	Max.21	Max.21	Max.21
7.4	Chromium (Cr)	mg/kg	Max.21	Max.21	Max.21
7.5	Mercury (Hg)	mg/kg	Max.0.6	Max.0.6	Max.0.6
8	Arsenic	mg/kg	Max.3.0	Max.3.0	Max.3.0
NOTE: The mass fraction is the weight/weight					

Source: SNI 3822:2018

RESEARCH METHOD

- Preparation

Data collection is divided into secondary data collection and primary data. The manufacture of standard solutions is one of the steps of activities in the collection of primary data carried out after the preparation of tools and materials. The coagulants in thisstudy used *Poly Aluminium Chloride* (PAC) type A.

Determination of the optimum dose of coagulant turning was determined using the Jar Test method.

- Tools and materials used:
  - Jartest (lovibond).
  - Electron balance
  - Glassware, consisting of beaker glass, measuring flask, pipet of various sizes
  - pH meter
  - Turbidimeter Hach 2100Q
  - PAC
  - Aquadest
- Sampling

The sample used in this study was raw water at PDAM Tirta Wening Bandung which was sourced from the Cisangkuy river and Cikapundung River. The two sources of raw water are mixed in the piping and then enter the reservoir.

- Turbidity and pH

Observe the magnitude of the floc size, Measurement of turbidity and final pH of the water sample was carried out after experiments using a Turbidimeter and pH meter.

RESULT AND DISCUSSION

From the results of jar test measurements for 28 days, data on the initial turbidity of raw water, turbidity after the jar test, the initial pH and after the jar test and the optimum dose of PAC coagulant as shown in table 2 were produced.

Turbidity

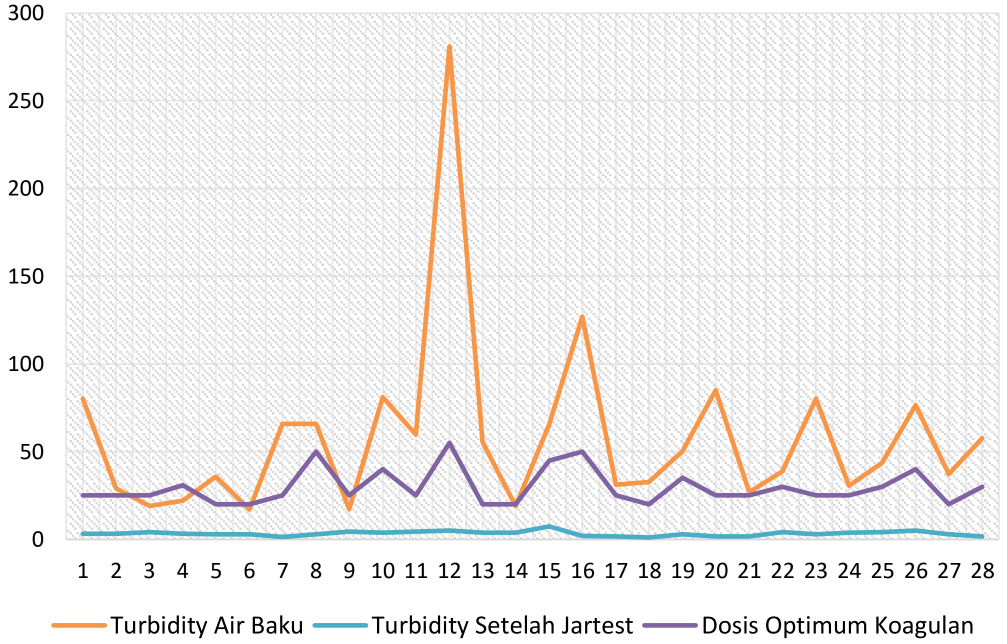
Turbidity is a condition where liquids cannot pass on light due to the number of soluble particles such as inorganic and organic materials trapped in water and can cause effects on, health, aesthetics and disinfection processes (Amir, 2008). Suspended particles (TSS) can result in increased turbidity in water (Darnoto and Astuti, 2009). The higher the turbidity, the higher the suspended solids in the water. This indicates the presence ofa positive correlation between turbidity and suspended particle levels. Suspended particles in water can be free and colloidal particles of very small size, such as dissolved solids having a particle size of <10-6 mm; colloids 10-6 – 10-3 mm, and suspended solids > 10-3 (Effendi, 2003). During floods, turbidity in river water is caused by large suspended particles. The average turbidity of raw water samples prior to the coagulation-flocculation processis above the maximum allowable threshold for drinking water quality requirements. The results of the analysis of the PAC coagulant jar test on the turbidity of raw water in the Badaksinga IPA can be seen in figure 3.

Table 2
Comparison Between Turbidity and pHPa da Raw Water and After Jartest

No	Date	Raw Water		Dose Optimum	Jartest Results	
		Turbidity (NTU)	pH	PAC (mg/l)	Turbidity (NTU)	pH
1	06-Sep	80,1	7,30	25	3,1	7,1
2	07-Sep	29,1	7,20	25	3,3	7,14
3	08-Sep	19,1	7,19	25	4,2	7,21
4	09-Sep	22,1	7,20	31	3,1	6,93
5	10-Sep	35,7	7,00	20	3,0	6,98
6	13-Sep	17,1	7,29	20	2,9	6,64
7	15-Sep	65,8	6,87	25	1,5	6,95
8	16-Sep	65,9	6,78	50	3,0	6,75
9	17-Sep	17,3	6,86	25	4,3	6,85
10	20-Sep	81,0	7,30	40	3,8	6,86
11	21-Sep	59,9	7,08	25	4,3	7,12
12	22-Sep	281,0	7,12	55	5,0	6,73
13	23-Sep	55,5	7,20	20	3,9	7,23
14	24-Sep	19,0	7,14	20	3,7	7,24
15	27-Sep	65,7	7,30	45	4,4	6,8
16	28-Sep	127	7,12	50	2,0	6,83
17	29-Sep	31,1	7,12	25	1,6	7,12
18	30-Sep	32,7	7,14	20	1,1	6,92
19	01-Oct	50,5	7,12	35	3,0	6,93
20	04-Oct	85,0	7,10	25	1,7	7,12
21	05-Oct	26,8	7,11	25	1,8	6,98
22	06-Oct	38,8	7,16	30	4,1	7,15
23	07-Oct	80,2	7,09	25	3,0	7,11
24	08-Oct	30,7	7,14	25	3,8	6,98
25	11-Oct	43,7	7,09	30	4,0	7,01
26	12-Oct	76,6	7,21	40	4,9	7,01
27	13-Oct	37,3	7,20	20	3,0	7,14
28	14-Oct	57,6	7,21	30	1,8	7,12
	Average	58,3	7,13	30	3,2	6,99

From the results of the examination, the turbidity of raw water ranged from 17.1 NTU to 281 NTU with an average of 58.3 NTU. The concentration of PAC solution added varies according to the turbidity of the raw water. In each experiment, the average concentration ranged from20 ppm to 50 ppm. For high turbidity, above 200 NTU, the added coagulant concentration is between 50 and 75 NTU. After jartest, an average turbidity of 3.2 NTU with a maximum range of 5.0 NTU and a minimum of 1.1 NTU was produced. Theaverage efficiency of the resulting turbidity is 94.5%

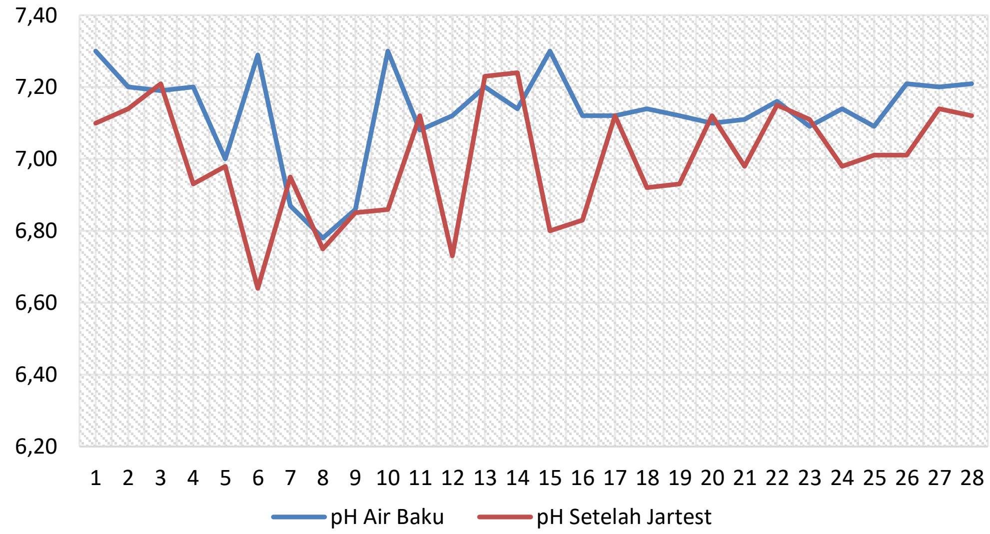
Figure 3
Turbidity Measurement Results in Raw Water, After Jartest and Optimum Dosage of Coagulant Used



pH (Acidity Degree)

pH is determined and measured from the H^+ and OH^- content contained in water. pH measurement is carried out every morning before and after the jar test which aims to determine the acidic or alkaline condition of raw water samples that will be used for clean water treatment. The pH value before the coagulation-floc processis already at the maximum allowable threshold of 6.5-8.5. The results of measuring the pH value in this study are as presented in table 2 and figure 4.

Figure 4
Comparison Between Raw Water pH
Before and After Jar test



Based on Figure 4. The average pH measurement after the grafting f-coagulation simulation processusing jartest conducted in the morning has a value with a range between 6.78 to 7.30. The measurement value after this pH is already below the maximum allowable pH threshold. The efficiency of a 4.1% decrease in pH is due to the release of hydrogen ions (H^{+}) For PAC coagulants, the resulting pH drop will be smaller compared to Aluminum sulfate, due to the release of more H^{+} ions, as in the reaction equations (1) and (2).

CONCLUSION

The andstrengths that can be taken from this study are:

The turbidity value of raw water varies from 17.1 to 281 NTU, fluctuating due to the geographical location and environmental conditions around each river, namely the Cisangkuy river and the Cikapundung River. After processing, the turbidity concentrationwas in the range of 1.1 to 5.0 NTU with an average turbidity reduction efficiency of 94.5%.

The average acidity of raw water is 7.13, this value has met the quality standard requirements, which is around 6.5-8.5. After the Jar Test, anaverage pH value of 6.99 was produced with a reduction efficiency of 4.1%. This is in accordance with one of the advantages of PAC, namely that its use does not cause too extreme a decrease in pH so that it can save the use of materials for neutralization and ultimately have an impact on reducing operational costs

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