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Research Article

Synthesis of $KAl(SO_4)_2$ Solid Coagulants from Used Pots and Beverage Cans

Sintesis Koagulan Padat $KAl(SO_4)_2$ dari Panci Bekas dan Kaleng Minuman Bekas

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Abstract

Used pots and beverage cans are good sources of aluminum-rich raw materials for the synthesis of potassium aluminum sulfate ($KAl(SO_4)_2$), a solid coagulant. The synthesis process includes preparation, dissolution, extraction, sedimentation, and drying. Therefore, this research aimed to determine the characteristics of $KAl(SO_4)_2$ synthesized from aluminum pots and beverage cans waste, adjusted to the quality requirements of commercial $KAl(SO_4)_2$ according to SNI 06-2102-1991 standard. The materials used were aluminum pots, as well as a mixture of pots and beverage cans, with varying concentrations of 20%, 30%, and 40% KOH solvent. The synthesis results, characterized by XRF (X-ray fluorescence), showed an Al content of 0.001-3%. In addition, the results of the data analysis, adapted to SNI 06-2102-1991 standard for potassium aluminum sulfate, indicated that the synthesis met the required parameters for water-insoluble parts, Fe, Pb, and As, and Al_2SO_3, which was close to the quality requirements.

Keywords: aluminum pots; beverage cans; coagulant; extraction; potassium aluminum sulfate

Abstrak

Koagulan padat kalium aluminium sulfat ($KAl(SO_4)_2$) dapat disintesis menggunakan bahan baku dengan kandungan aluminium tinggi, seperti panci dan kaleng minuman bekas. Proses sintesis meliputi preparasi, pelarutan, ekstraksi, sedimentasi, dan pengeringan. Oleh karena itu, penelitian ini bertujuan untuk mengetahui karakteristik $KAl(SO_4)_2$ hasil sintesis dari limbah panci dan kaleng minuman aluminium, yang disesuaikan dengan persyaratan mutu $KAl(SO_4)_2$ komersial menurut standar SNI 06-2102-1991. Bahan yang digunakan adalah panci aluminium, serta campuran panci dan kaleng minuman, dengan variasi konsentrasi pelarut KOH 20%, 30%, dan 40%. Hasil sintesis yang dikarakterisasi dengan XRF (X-ray fluorescence) menunjukkan kadar Al sebesar 0,001-3%. Selain itu, hasil analisis data yang disesuaikan dengan standar SNI 06-2102-1991 untuk kalium aluminium sulfat menunjukkan bahwa sintesis tersebut memenuhi parameter yang disyaratkan untuk bagian yang tidak larut dalam air, Fe, Pb, dan As, serta Al_2SO_3, yang mendekati persyaratan mutu.

***Kata kunci**: ekstraksi,;kaleng minuman,;Kalium Aluminium Sulfat,;koagulan,;panci aluminium*

1. Introduction

The increasing population in Indonesia has caused the production of both organic and inorganic waste. One type of inorganic waste that is widely produced is aluminum waste, which requires approximately 400 years to decompose [1]. In this regard, household activities generate about 38.13% of Indonesia's waste, with 3,520 tons of aluminum waste produced daily in 2022 [2]. The current waste management is still limited to collecting and selling without prior processing, even though the aluminum content in pots and beverage cans can be reused by recycling [3].

The percentage of aluminum content in used pots ranges from 97.93% to 99.05% [4], while beverage cans percentage ranges from 92.5% to 97.5% [3]. The high aluminum content in used pots and beverage cans can be synthesized into coagulants, which form flocs by coagulating suspended solid particles, dyes, and colloids [5]. The coagulant formed from this synthesis include Potassium Aluminum Sulfate ($KAl(SO_4)_2$), which is commonly used in wastewater treatment, purification, and fire extinguishers [6].

$KAl(SO_4)_2$ coagulant can be formed from aluminum materials, and several brands of pots in the community have a high percentage of aluminum. Furthermore, the Eagle brand pots contain 99.05% aluminum, Djawa contains 99.26%, and Orchid contains 97.93% [4]. The aluminum content of used beverage cans of the Pocari Sweat brand is 96.38%, Cap Kaki Tiga is 89.74%, Greensand is 90.87%, and Coca-Cola is 93.28% [7],[8].

Solid-liquid extraction is used in the synthesis of $KAl(SO_4)_2$ because it can dissolve certain substances in solid materials. Factors affecting the formation of $KAl(SO_4)_2$ include the concentration of solid base solvents (KOH) and solid acids (H_2SO_4), the precipitation process, and drying [9]. The amount of aluminum content synthesized can be affected by the solvent used, such as KOH. In addition, H_2SO_4 plays a role in the precipitation of dissolved aluminum, and drying affects the water content of the final product [10].

Aluminum is extracted from used beverage cans to produce coagulants with a high yield percentage of 97.95% and a water turbidity removal efficiency of 70% [11]. Moreover, reacting 1 g of used beverage cans in 30% KOH and 8 M H_2SO_4 and drying the mixture at 50°C, can produce 14.8 g of $KAl(SO_4)_2$ [9]. Similar research had produced coagulants with physical form, odor, pH, and quality characteristics almost identical to commercial $KAl(SO_4)_2$ [12]. It can also be synthesized from aluminum spoons and food containers and applied in raw water treatment [13]. Furthermore, its synthesis with aluminum foils as the base materials can produce coagulants with an Al_2SO_3 content of 15.18% [14]. Therefore, this research aimed to determine the characteristics of $KAl(SO_4)_2$ synthesized from aluminum pots and beverage cans waste, adjusted to the quality requirements of commercial $KAl(SO_4)_2$ according to SNI 06-2102-1991 standard.

2. Research Methods

2.1. Tools and Materials

The raw materials used were aluminum pots and Pocari Sweat brand beverage cans. The materials used in the synthesis process included KOH, H_2SO_4, and distilled water. In this research, the equipment consisted of an analytical balance, drying oven, desiccator, and XRF

(X-Ray Fluorescence) Spectrometer AMETEK, which aimed to determine the composition of metal content with quantitative data.

2.2. Sample Preparation

The initial stage to prepare the raw materials, namely used pots and beverage cans, included cleaning with coarse sandpaper, cutting into approximately 1 cm in size, and soaking in hot water for a few moments. Therefore, this stage removed visible impurities, and the preparation process aimed to adjust the size and shape of the raw materials before the next process.

2.3. Sample Dissolution Process

The dissolution process aimed to dissolve the raw materials using KOH to produce potassium aluminate. In this research, the concentration of KOH solvent was varied by 20%, 30%, and 40% in a volume of 50 mL. At each concentration variation, 1 g of pots as variation A and 0.5 g of pots + 0.5 g of beverage cans as variation B were added into the KOH solvent. The dissolution process was carried out on a hot plate at 50°C.

2.4. Extraction Process of $KAl(SO_4)_2$

Potassium aluminate filtrated from the sample dissolution process (45 mL) was reacted with sulfuric acid reagent (H_2SO_4) in a volume of 30 mL, maintaining a ratio of 3:2. In this process, H_2SO_4 was gently dripped into the filtrate and stirred continuously. Occasionally, a few drops of distilled water were added to prevent clumping.

2.5. Precipitation and Drying Process

The precipitation process was carried out by placing the extracted solution inside the freezer for 1 hour at a temperature of 7°C. Subsequently, the resultant $KAl(SO_4)_2$ was washed using 50% ethanol. Drying was conducted using a drying oven at a temperature of 50°C for 1 hour and continued until a product with a constant weight was produced.

3. Results and Discussion

3.1. Synthesis Process

Dissolving aluminum using KOH is a reduction-oxidation (redox) reaction. This reaction released H_2 gas, indicated by the appearance of bubbles and smoke during the process. Furthermore, the bubbles and smoke were produced by the reaction between aluminum pieces from pots or cans and aluminum cations [15]. This process was exothermic, and released heat into the environment as well as produced bubbles. The reaction was concluded when no more bubbles were formed, and filtration was carried out to separate the potassium aluminate filtrate from other impurities. The reaction in the extraction process using H_2SO_4 was denoted as follows:

$$2Al_{(s)} + 2KOH_{(aq)} + 2H_2O_{(l)} \longrightarrow 2KAlO_{2(aq)} + 3H_{2(g)}$$

$$2KAlO_{2(aq)} + 2H_2O_{(l)} + H_2SO_{4(aq)} \longrightarrow 2Al(OH)_{3(s)} + K_2SO_{4(aq)}$$

$$2Al(OH)_{3(s)} + 3H_2SO_{4(aq)} + K_2SO_{4(aq)} \longrightarrow 2KAl(SO_4)_{2(aq)} + 6H_2O_{(l)}$$

Figure 1. Physical form of $KAl(SO_4)_2$

Adding H_2SO_4 affects the formation of the $KAl(SO_4)_2$ coagulant as it precipitates the aluminum bound by the KOH solution. Therefore, this reaction produced an $Al(OH)_3$ white residue, excess H_2SO_4 was added to dissolve $Al(OH)_3$, and distilled water was occasionally added while stirring continuously [13]. Figure 1 shows the physical form of $KAl(SO_4)_2$ from the research results.

3.2. Characterization Results

The synthesis of $KAl(SO_4)_2$ coagulant used materials with high aluminum content as the basic element. Testing of the coagulant product was needed to determine the amount of extracted aluminum content. Moreover, testing the characteristics using XRF aimed to determine the metal content with data presented quantitatively. The XRF testing used the AMETEK XRF Spectrometer instrument to determine a material's chemical composition. Also, testing the characteristics of $KAl(SO_4)_2$ was conducted using the SNI 06-2102-1991 standard to compare the quality requirements of the same product. The results of the product characterization showed that the elements with the largest percentage were dominated by Potassium (K), Aluminum (Al), and Sulfur (S). This was because the elements forming $KAl(SO_4)_2$ consisted of Potassium, which originated from a strong base as a solvent, Aluminum from pots and cans, as well as Sulfur from H_2SO_4 in fairly high amounts. In this research, the concentration of KOH did not affect the percentage of extracted K because KOH only acted as a solvent. Testing the characteristics of $KAl(SO_4)_2$ was conducted using SNI 06-2102-1991 standard to compare the quality requirements of the same product that had been traded.

Table 1. Characterization Results

Parameter	**Sample**						**Standard SNI 06-2102-1991**
	A1	**A2**	**A3**	**B1**	**B2**	**B3**	
Water Insoluble Part (%)	0.00238	0.012	0.0246	0.0112	0.0114	0.0212	Max 0.5
Al_2O_3 (%b/b)	0.1016	6.266	0.4193	2.533	0.00255	1.773	Min. 8
Fe (%b/b)	<0.00013	0.00277	<0.00019	0.00259	<0.00015	<0.00015	Max. 0.01
Pb (mg/kg)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	Max. 50
As (mg/kg)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	Max. 50
K (%b/b)	0.00009	6.845	1.925	1.986	0.00125	2.698	-
S (%b/b)	1.529	1.300	5.645	4.554	9.49	4.593	-

Description:
A1: Pots and 20% KOH solvent
A2: Pots and 30% KOH solvent
A3: Pots and 40% KOH solvent
B1: Pots + Cans and 20% KOH solvent
B2: Pots + Cans and 30% KOH solvent
B3: Pots + Cans and 40% KOH solvent

Table 1 shows that the parameter of the water insoluble part met the quality requirements, which was below 0.5%. The water-insoluble part is a non-polar substance that does not dissolve when reacting with water [16]. The $KAl(SO_4)_2$ product synthesized from used beverage cans met the parameter requirements for the water-insoluble part, which was below 0.5%. This parameter indicated the amount of impurity in the product. The greater the impurity in alum, the greater the percentage of the water-insoluble part [9].

The Al_2O_3 content value from the synthesis of the $KAl(SO_4)_2$ coagulant did not meet the standard requirements based on SNI 06-2102-1991 because it ranged from 0.00255% to 6.266%. Moreover, the Al_2O_3 content produced did not meet the standard requirements contained in SNI 06-2102-1991 because the raw materials of $KAl(SO_4)_2$ were different from commercial $KAl(SO_4)_2$, namely bauxite [1]. The synthesis of $KAl(SO_4)_2$ based on aluminum foil packaging produced a product with an Al_2O_3 content of 15.18% [16]. Although the synthesis materials were also derived from the packaging materials, the type of raw materials and the amount of aluminum content from previous analyses differed from that of this research. Therefore, the resulting product differed, especially for the Al_2O_3 content.

Chemical parameters in the form of Fe content were in the range below 0.00013% to 0.002%. This value was still below the SNI standard, which was <0.01%. The low Fe content characterization results can be attributed to very low Fe content in the raw materials, leading to very small extracted content. Meanwhile, Pb (lead) met the SNI 06-2102-1991 standard with a value below 0.3 mg/kg. The As (arsenic) parameter also met the standards required in SNI 06-2102-1991, being below 0.2 mg/kg. Arsenic metal content exceeded the threshold and can cause arsenic pollution [17]. In addition, analysis of metal components in the $KAl(SO_4)_2$ product showed the values were safe, and confirmed that used pots and beverage cans were safe to be synthesized into $KAl(SO_4)_2$ coagulant.

3.3. The Effect of KOH on the Weight of $KAl(SO_4)_2$

KOH is a strong base characterized by a white solid form with high solubility in water and forms salt when reacted with acid [9]. The weight of $KAl(SO_4)_2$ produced from this research is presented in Figure 2. The results showed a relationship between the concentration of KOH solvent and the weight of $KAl(SO_4)_2$ produced.

The relationship was directly proportional, meaning that the higher the concentration of KOH solvent used, the higher the weight of $KAl(SO_4)_2$ produced. Previous research on alum formation stated that a constant volume with varying concentrations of KOH base solvent affected the amount of $KAl(SO_4)_2$ produced. Specifically, the higher the concentration of KOH, the more alum was formed [18]. However, in this research, the complex content of pots and cans caused the amount of Al extracted to be indirectly proportional to the increase in KOH concentration.

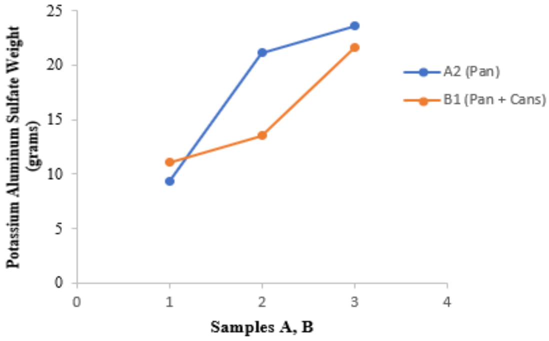

Figure 2. Graph of the Effect of KOH on $KAl(SO_4)_2$

4. Conclusion

In conclusion, based on the XRF characterization results and data analysis, the Al_2O_3 parameter was still below the standard requirements. Compared to other variations, used aluminum pots materials with a KOH concentration of 30% and aluminum pots + beverage cans with a KOH concentration of 20% produced Al_2O_3 content close to the quality standard requirements according to SNI 06-2102-1991. Also, when viewed from the comparison of raw materials used, aluminum pots materials produced coagulants with characteristics closest to the reference according to the quality requirements of $KAl(SO_4)_2$.

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