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The Effectiveness of Alum Made of Uncoated Aluminium Foil Waste in Improving the Quality of Liquid Waste of the Tofu Industry

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ABSTRACT

Aluminium foil waste increases every year in line with technology development, especially in the food and beverage industry. It will cause significant environmental problems because the packaging cannot be destroyed in the soil. Therefore, it is necessary to reprocess a large amount of aluminium waste into an alternative product such as alum which can be applied directly to the treatment of liquid tofu waste. In this study, uncoated aluminium foil waste was used, which was taken at random landfill sites and then washed and cut into small pieces. Dissolution of aluminium using KOH solution then the solution obtained is reacted with H_2SO_4 solution and the reaction is carried out at a temperature of 70^oC. The experimental results got a maximum yield of 63.69% with Al_2O_3 content of 15.18% using 3 M KOH concentration and 5 M H_2SO_4 concentration. The obtained alum was then applied to the tofu industrial liquid waste. With the use of 800 ppm alum, there was a 60% decrease in the colour content of the Pt-Co unit, a 95.8% decrease in NTU and a 63.33% decrease in TDS. The quality of the liquid waste obtained met the technical requirements of raw water that can be treated by SNI 6773: 2008.
Keywords : *Aluminum Foil; Uncoated; Alum; Wastewater.*

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ABSTRAK

Limbah aluminium foil setiap tahun selalu mengalami peningkatan sejalan dengan berkembangnya kemajuan teknologi terutama dibidang industri makanan dan minuman, sehingga akan menimbulkan masalah besar bagi lingkungan karena kemasan tersebut tidak bisa hancur didalam tanah. Maka dari itu perlu dilakukan pengolahan kembali limbah aluminium yang berjumlah sangat besar menjadi suatu produk alternatif seperti tawas yang bisa diaplikasikan langsung pada pengolahan limbah cair tahu. Pada penelitian ini digunalan limbah aluminium foil ancoted dicuci bersih selanjutnya dipotong menjadi berukuran kecil. Pelarutan aluminium menggunakan larutan KOH kemudian direaksikan dengan larutan H_2SO_4 pada suhu 70^0C. Dari hasilpercobaan diperoleh rendemen maksimal 63,69% dengan kadar Al_2O_3 sebayak 15,18% pada pemakaian konsentrasi KOH 3M dan konsentrasi H_2SO_4 5M. Tawas yang diperoleh kemudian diaplikasikan pada limbah cair industri tahu dan dengan pemakaian 800 ppm tawas terjadi penurunan kadar warna unit Pt-Co 60%, penurunan NTU 95,8% dan penurunan TDS 63,33% dan kualitas limbah cair yang diperoleh sudah memenuhi persaratan teknis kualitas air baku yang bisa diolah sesuai dengan SNI 6773: 2008.
Kata kunci : aluminium foil; uncoated; tawas; limbah cair.

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INTRODUCTION

Aluminium foil is a thin sheet-like paper made of an aluminium alloy containing up to 99.4% aluminium thickness of about 0.2 mm. Aluminium foil is widely used as a wrapper in the food industry, both on a large and small scale, in the pharmaceutical industry as packaging for certain drugs, in medicine and health, in chemical and microbiology laboratories, glassware packaging so that it is sterile. Aluminium foil is widely used as a wrapping material because it has distinctive properties such as being non-toxic, resistant to heat and water vapour, easy to shape in use so that it can make it easier to use during the sterilization process, is corrosion resistant and has high thermal conductivity [1]. In addition to its advantages, aluminium foil can also cause negative impacts that cannot be ignored for the environment. The use of aluminium foil always increases every year, causing an increasing amount of waste because the aluminium foil is an inorganic material that is very difficult to destroy in the soil. Pollution caused by solid waste aluminium foil on the environment is getting worse. It must immediately get serious attention from the wider community and the government so that the domain does not suffer damage and lose land, water and air [2]. Considering the lousy impact caused by the use of aluminium foil, it is necessary to find a way out, namely to recycle waste so that it can be used as an alternative material for industrial wastewater treatment.

The tofu industry produces waste which can be grouped into two, namely solid waste and liquid waste. Solid waste has been used as fodder for livestock, and some are made of flour for specific food preparations. In contrast, the liquid waste has not been processed optimally and even directly dumped into the river [3]. In 1 kg of soybeans processed into tofu can produce about 35-45 litres of liquid waste consisting of protein, fat, carbohydrates and suspended solids [4][5]. Tofu liquid waste is organic waste that can easily cause unpleasant odours if not treated immediately. Tofu waste is usually thicker than pure water, slightly yellow, has a pungent, sour smell and has a temperature above 40^{o}C with a TSS content of 5603 mg/l. Meanwhile, according to the regulation of the Ministry of Environment No. 5 of 2015, it is stated that the quality standard of tofu waste contains a maximum TSS of 200 mg/l. Referring to the regulation, the liquid waste tofu must be processed first before being drained by the river body so that it does not poison the biota in the river flow [3].

Several studies have been carried out in the context of reprocessing aluminium packaging waste which aims to preserve the environment and increase the economic value of the trash. Research conducted by [6][7][8][9][10]concluded that alum obtained from aluminium waste in the form of used cans could be used for water purification processes, only from these studies each get different yields and quality because the Al content of the raw materials used is other. Alum from used beverage cans can also reduce iron, manganese, and calcium levels in acid mine water treatment [11][12].

To manufacture coagulants [13], use plain aluminium foil packaging and coloured aluminium foil. Under the same conditions, the alum produced from plain aluminium foil had an Al2O3 content of 11.85%, while the Al2O3 blood-coloured aluminium foil was only 4.89%. It turns out that aluminium waste can be used to produce hydrogen gas with the highest conversion achieved at a NaOH concentration of 6 N and a reaction time of 5 minutes which is 51.346%. The yield of hydrogen produced reaches 6.229% [14].

Based on the results of previous research, it is still necessary to develop a more effective way of recycling aluminium foil waste and applying the product obtained to reach the target. Researchers plan specifically to treat uncoated aluminium foil waste using KOH and H_2SO_4 reactants at specific concentrations in the hope of producing a product in the form of alum or potassium aluminium sulfate $KAl(SO_4)_2.12H_2O$, which will be applied to the tofu industrial wastewater. It is hoped that the obtained from the recycling of aluminium foil can be used directly to the liquid waste of the tofu industry so that a clean environment is obtained, free from solid aluminium foil waste and tofu waste that flows into the river does not damage the biota in the river flow. This is by the statement [15] that alum is a type of coagulant widely used in water purification processes, especially for urban industrial waste that contains high total solid and dyes to meet household water needs. The study aimed to obtain the best method and composition for manufacturing $KAl(SO_4)_2.12H_2O$ alum made from uncoated aluminium to get the maximum yield.

The benefit of the research is to provide information to the public that aluminium foil waste can be recycled into $KAl(SO_4)_2.12H_2O$ alum which can be applied directly to the tofu industrial wastewater treatment to reduce the amount of aluminium foil waste that cannot be destroyed in decades and can reduce the exploitation of bauxite mining which is a non-renewable natural resource.

LITERATURE REVIEW

Raw materials

Aluminium is the most abundant type of silvery-white metal, clay, lightly forged, durable and lightweight, so it is widely used in various industries and household appliances. The most prominent use is as a material making cans and aluminium foil. Aluminium is also readily soluble in acidic solutions. Aluminium can be oxidized on its surface when exposed to air, but the oxide layer can protect the inner object against further oxidation. Aluminium is the most valet ion in its compounds. Ions (Al^{+3}) can form colourless salts with colourless anions. Aluminium sulfate can only be made in a solid-state, in a solution of water will be hydrolyzed to form aluminium hydroxide $Al(OH)_3$. Aluminium sulfate forms double salts with sulfates of monovalent cations with crystalline forms called alums.

Aluminium that has undergone several processes exists in thin sheets with a thickness of less than 0.2 mm. Aluminium sheets with a thickness of fewer than 150 microns called aluminium foil is a layer of alloy containing 99.4% aluminium. Aluminium foil can be made in various forms depending on its use, such as food and beverage packaging. Aluminium foil is very wide because it has many advantages. It includes being impervious to air, water, and fat, does not affect taste and smell and is clean but easily damaged due to sam, kitchen salt and heavy metals.

Potassium hydroxide (KOH) is a white or yellow solid crystal. It is a compound in the strong base group that is easily soluble in water with solubility in water (25ºC): 1100 g / L. When reacted with acids, they form salts and can react with CO_2 in the air to form K_2CO_3 and water.

Sulfuric acid (H_2SO_4) is a viscous oil-like liquid, colourless, and a strong acid that is highly corrosive to metals, reacts violently with exothermic water and is a polar compound that can be used as a solvent for organic compounds.

Products

Alum is a hydrogenated double sulfate salt with $M^{+}M^{+3}(SO_4)_2.12H_2O)$, where M^{+} is a univalent cation. Alum, commonly known as aluminium sulfate dodecahydrate, is widely used in clean water treatment plants that are more popular with alum. In contrast, potassium alum is widely used for sewage treatment. Potassium alum is a colourless and crystal-shaped compound. The solution is acidic and easily soluble in water. Alum is widely used as a coagulant in water treatment and liquid waste because it effectively attracts particles in the colloidal and suspended form [16]. It is called flocculation because it can clump colloidal particles together to form large clumps and quickly deposit or filter. Alum has significant adsorb power because it can absorb dirt, toxins, odours, etc. The primary material for making alum is aluminium metal. Aluminium is a metal that is widely used in everyday life, such as for household appliances, construction, electricity, electronic equipment, and the packaging industry in aluminium foil. Many aluminium foil waste is wasted and causes problems for the environment due to waste hoarding that is difficult to destroy. In contrast, aluminium foil waste can still be recycled into alum that can be utilized for waste treatment.

The manufacture of aluminium foil waste is uncoated using potassium hydroxide (KOH) and sulfuric acid (H_2SO_4). The reactions that occur at the time of the addition of KOH solution to aluminium foil are as follows [17]:

$$2\,Al(s) + 2\,KOH(aq) + 6\,H_2O(l) \longrightarrow 2\,KAl(OH)_4(aq) + 3\,H_2(g) \quad (1)$$

The addition of KOH binds the Al^{+2} cations contained in the aluminium foil to form $KAl(OH)_4$, which is easily soluble in water and the formation of hydrogen gas bubbles. The reaction is exothermic, and the reaction is complete after the gas bloat is gone. And to speed up the reaction, heating is carried out at around 70°C. The addition of KOH needs to be made in excess to avoid the formation of $Al(OH)_3$.

The obtained filtrate was filtered to separate the impurities in the form of residue, and then the clear solution got was reacted with sulfuric acid (H_2SO_4). The reaction is as follows:

$$2\,KAl(OH)_4(aq) + H_2SO_4(aq) \longrightarrow 2Al(OH)_3(s) + K_2SO_4(aq) + 2\,H_2O(l) \quad (2)$$

The H_2SO_4 solution will react perfectly with $KAl(OH)_4$, then the formed $Al(OH)_3$ reacts directly with excess H_2SO_4 so that the following reaction occurs:

$$2Al(OH)_3(s) + 3\,H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 6H_2O(l) \quad (3)$$

A clear solution of $Al_2(SO_4)_3$ is formed in this reaction. It will then react again with K_2SO_4 as a result of a reaction (2) and the development of a reaction (3) in the form of a saturated solution, and when cooled, it will form white crystals, which are thought to compound $KAl(SO_4)_2.12H_2O$ with the following reaction:

$$K_2SO_4 + Al_2(SO_4)_3 + 12\,H_2O \longrightarrow KAl(SO_4)_2.12H_2O \quad (4)$$

$KAl(SO_4)_2.12H_2O$, alum crystals obtained then washed using 50% ethanol solution to accelerate drying. Alum that has good quality by the requirements listed in SNI 0032-2011 is in the form of crystals (lumps) or powder, and some are in the form of granules, clear colourless with Al_2O_3 content above 17%.

Coagulants such as alum, Poly Aluminum Chloride (PAC), ferrous sulfate and organic polyelectrolytes are usually used to reduce water turbidity in WWTPs [15]. As for how to use alum in WWTP, namely, putting it into wastewater and then stirring it so that the ions from dissolving alum spread around the water molecules. The equation for the reaction is as follows:

$$KAl(SO_4)_2.12H_2O(s) + H_2O(l) \longrightarrow K^+(aq) + Al^{+3}(aq) + 2(SO_4)^{-2}(aq) + 12H_2O(l) \quad (5)$$

Then Al^{+3} ions in water will be hydrolyzed and form colloid $Al(OH)_3$ with the following reaction equation:

$$Al^{+3}(aq) + 3\,H_2O(l) \longleftrightarrow Al(OH)_3(s) + 3H^+(aq) \quad (6)$$

The colloidal particles present in the waste will be combined with colloids derived from aluminium due to the difference in charge between the particles in the system, thus forming large clumps and merging into the mud, or a coagulation process occurs. The main factors affecting the waste's coagulation and flocculation process are the number of suspended solids, turbidity in the composition and concentration of anions and cations, pH, temperature, coagulant dose, stirring speed and duration of stirring and the presence of coagulant.

RESEARCH METHODS

Materials and Equipment

The materials used are solid waste aluminium foil uncoating randomly taken at the disposal site of waste, industrial tofu liquid waste, KOH solution concentration 2M, 3M, 4M, 5M, H_2SO_4 solution concentration 5M, 7M, 9M, ethanol solution 50% and aqua dest. The equipment used are hot plate, filter paper #41, dividing funnel, 100 ml measuring glass, beaker glass 500 ml, Erlenmeyer 250 ml, turbidimeter variant DMS 80, UV Visible spectrophotometer, and atomic absorption spectrophotometer AA-6200.

Research Variable

The fixed variables determined in the study were 3 grams of uncoated aluminium foil waste, 100 ml of KOH solution volume, 100 ml of H_2SO_4 solution, 50 ml of ethanol volume, 700C heating temperature. Variables determined in the study: KOH concentration: 2M; 3M; 4M; 5M. And the concentration of H_2SO_4: 5M; 7M; 9M.

The procedure of making alum or potassium aluminium sulfate $KAl(SO_4)_2.12H_2O$

The process of making alum from uncoated aluminium foil waste consists of several stages, namely:

a. Preparation. Preparation of raw materials, namely uncoated aluminium foil waste, is collected randomly, washed, and then cut into small pieces to facilitate the dissolving process.
b. Solution Step. Waste aluminium foil that has been cut and then weighed as much as 3 grams is put into an Erlenmeyer, then 100 ml of KOH solution is added with a predetermined concentration according to the variables (2M, 3M, 4M, 5M) then heated at a temperature of 70°C hot plate while stirring until the gas bubbles bubble. Exhausted, and all the aluminium has melted. The results of the dissolution process are then cooled to room temperature and then filtered using filter paper.
c. Alum Disposition. The filtrate obtained at point c is added 100 ml of H_2SO_4 solution with a concentration of (5M, 7M, 9M) slowly and heated at 70°C until a clear solution is obtained and filtered using Whatman 41 filter paper. 30°C and white crystals were obtained.
d. Washing and drying.. The washing process was carried out using 50 ml of 50% ethanol which aims to speed up drying and then dried in an oven at a temperature of 105°C, then weighed, and the yield was calculated.
e. Calculating % yield of alum can be used the following equation:
% Rendemen = (yield weight/ theoretical weight) x 100%
Theoretical weight = raw material weight W % Al x Mr [$KAl(SO_4)_2.12H_2O$] / Mr Al.
f. Quality test. From the most significant yield results, the quality test is then carried out. The results obtained are then carried out by SNI 0032-2011 quality test.
g. Performance test. The performance test of the alum produced was applied to the tofu industrial liquid waste by using alum levels ranging from 200 ppm, 400 ppm, 600 ppm and 800 ppm. Then the turbidity test was carried out based on SNI 06-6989.25-2005, colour test based on SNI 6989.80 - 2011, Total Dissolved Solids (TDS) test based on SNI 6989.27-2019.

RESULTS AND DISCUSSION

Aluminium foil packaging on the market has different levels of Al depending on its function and use. Uncoated aluminium foil is generally used for packaging milk, medicine, pharmacy, laboratories, printing businesses, etc. This study used random raw materials, then cleaned and cut into pieces using a sample weight of 3 grams. From the initial analysis results obtained, Al content is 72%.

Theoretical weight = raw material weight W % Al x Mr $KAl(SO_4)_2.12H_2O$ / Mr Al

= 3 x 0,72 x 474 / 27 = 37,92 gram

Calculating % Yield = yield weight/ theoretical weight x 100 %

The yield of 3 grams of aluminium foil with 2M KOH solvent and reacted with 5 M H_2SO_4 obtained the following results:

% Rendemen = 19,90 / 37,92 x 100% = 53,51 %. With the same calculation, the results can be tabled as follows

Tabel 1. Alum Yield of Research Results

KOH (M) 50 ml	H2SO4 (M) 50 ml	Yield weight Average (gram)	Alum weight Theoretical (gram)	Rendemen (%)
2	5	19,92	37,92	53,51
2	7	21,33	37,92	56,39
2	9	22,14	37,92	58,39
3	5	24,15	37,92	63,69
3	7	21,94	37,92	57,89
3	9	18,75	37,92	49,45
4	5	17,22	37,92	45,11
4	7	20,14	37,92	53,11
4	9	18,78	37,92	49,53
5	5	15,75	37,92	41,54
5	7	14,33	37,92	37,80
5	9	13,99	37,92	36,90

Table 1 shows that alum's yield ranged from 36.4% to 63.69%. The result was obtained at a concentration of KOH 5M with H_2SO_4 9 M with a weight of 13.99 grams of alum, while at a concentration of KOH 3 M and a concentration of H_2SO_4 5 M obtained alum weight of 24.15 grams which is the highest yield. So the average yield of the research is 50.26%.

From the experiment, the lower the KOH concentration, the reaction that occurs with Al(s) runs slowly. The slow formation of H_2 gas bubbles, and the higher the concentration of KOH, the faster the formation of H2 gas bubbles, which means the quicker the $KAl(OH)_4$ solution is formed shown in reaction (1). The data in table 1 on the concentration of 2M KOH with the attention of H_2SO_4 (5 M, 7 M, 9 M) resulted in a low yield, which was strongly influenced by a relatively high level on average 56.05% when compared to a 5 M KOH concentration resulting in the lowest yield with an average 38.75%. In comparison, the maximum yield was obtained at a concentration of 3 M KOH with a concentration of 5M H_2SO_4, 63.69%, with a weight of 24.15 grams. The product obtained is primarily determined by the Al content of the material used in this case is the Al content of the aluminium foil, the concentration of KOH as a solvent and the concentration of H_2SO_4 as the alum-forming reactant, the reaction temperature, and also stirring.

The study results in the best conditions where the maximum yield was obtained, namely 63.69%, then alum received, were tested for product analysis and compared with the quality standard of SNI 0032 – 2011.

Tabel 2. Alum Product Analysis Results Results

Parameter	Unit	Alum result study	Alum (Standards)*
Al_2O_3	%	15,18	Min 17
The undissoved part	%	1,52	Maks 0,5
Fe	%	0,0009	Maks 0,007
Pb	mg/kg	<1,75	Maks 50
As	mg/kg	4,95	Maks 50
H_2SO_4 free	%	<0,1	Maks 0,1

*) SNI 0032- 2011

Table 2 shows that the level of Al_2O_3 according to the SNI quality requirements is at least 17%, and the alum produced from the research results is a maximum of 15.18%, while all other parameters meet the SNI standard. Although the level of Al_2O_3 in alum research results is lower than SNI, it is not a problem because the main target in this study is for internal use, such as the use of WWTP in the tofu industry. If the resulting alum contains Al_2O_3, which is small or lower than the SNI quality standard, it is used as a coagulant in the WWTP. Then in its application, it will require a higher amount when compared to commercial alum.

The alum produced can be used as a coagulant. A performance test of the alum produced is carried out on the liquid waste of the tofu industry. Alum is used as a coagulant because it can stabilize the colloidal charge of suspended solids so that fine floc is formed, which can be precipitated. These fine flocs that have been formed are then combined with slow stirring to form large flocs that are quickly deposited.

When the coagulant is reacted with tofu wastewater, the colloidal particles in the tofu waste will undergo a merging process from small particles to large ones due to the difference in charge between the colloidal particles and the coagulant from alum. Below are the results of the effectiveness test of alum in tofu industrial wastewater.

Tabel 3. Test Results of the Effectiveness of Alum on Tofu Industrial Liquid Waste

Alum Concentration (ppm)	Color (unitPt-Co)	Degradation %	Turbidity (NTU)	Degradation %	TDS (mg/L)	Degradation %
Blangko	0,55	-	670	-	5,350	-
200	0,30	45	35	94,78	4,010	25,05
400	0,25	54	32,1	95,20	2,985	44,21
600	0,22	60	30,4	95,46	2,036	61,94
800	0,20	64	28,2	95,80	1,855	63,33

Table 3, the results of testing the effectiveness of alum show that the higher the level of alum used, the higher the quality of the tested tofu industrial wastewater. This can be seen in the decrease in colour units which have initially been worth 0.48 units of Pt-Co after added alum. The 800 ppm colour unit experiment became 0.20 Pt-Co units, which means it can reduce the colour unit by 64% and the Normal Turbidity Unit (NTU), which was originally valued at 670 and after adding alum to 28.2, it decreased by 95.8%. In contrast, total dissolved solids (TDS) dropped from 5,350 to 1,855, reducing 63.33%. From the results obtained, it turns out that the liquid waste of the tofu industry that has been given 800 ppm alum from the research results can meet the standard of raw water quality that can be treated, by SNI 6773:2008 part of the technical requirements for the quality of natural water that can be processed by the Drinking Water Treatment Plant (IPA), namely maximum turbidity 600 NTU or 400 mg/L SiO2; colour content does not exceed 100 units of Pt-Co. It is hoped that the tofu industry will make WWTPs and make their alum from aluminium foil waste, which is often found in solid waste storage sites, to directly provide jobs for the surrounding community and reduce solid waste cannot be decomposed in decades.

CONCLUSION

From the research can be concluded as follow:

1. Uncoated aluminium foil waste with an average aluminium of 72% can produce potassium aluminium sulfate, $KAl(SO_4)_2.12H_2O$ or alum.
2. The optimal yield reached 63.69%, with the level of Al_2O_3 15.18% obtained by processing 3 grams of uncoated aluminium foil using KOH 3M concentration and H_2SO_4 5M concentration.

The resulting alum can improve the quality of liquid waste industry tofu. The maximum use of alum was achieved at a concentration of 800 ppm. There is a decrease in colour units (Pt-Co units) in the waste by 58.33%, a decrease in NTU by 95.8%, and a decrease in TDS by 65.34%. the performance of alum in tofu waste can meet the quality standards of raw water that can be treated according to SNI 6773:2008.

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