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SYNTHESIS OF POTASH ALUM FROM WASTE ALUMINUM FOIL AND ALUMINUM SCRAP

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ABSTRACT

The synthesis of potash alum from aluminum foil and aluminum scraps was carried out in this study. The aluminum wastes were dissolved in potassium hydroxide to form a complex aluminate. The solution was filtered and sulphuric acid was then added to the aluminate, heated and the resulting product was cooled in an ice bath. The analysis of the synthesized alum confirmed the presence of potassium, aluminum, sulphate, water of crystallization and a melting point of 92°C. The yield from aluminum foil was 15.35 g (76%) and aluminum scrap was 12.74 g (63%). The synthesized alum was found to be more effective than the commercially available alum in the treatment of muddy and waste water from fast food industry. The synthesized alum reduces the turbidity level of the muddy and waste water from fast food industry (1839 and 2305 NTU) to 169 (90.8%) and 34 NTU (98.5%) respectively, while the commercial alum in muddy water with initial turbidity level of 1839 NTU was reduced to 221 NTU (88%) and the turbidity level in waste water from fast food industry was reduced from 2305 NTU to 74 NTU (96.8%). The use of synthesized alum in water treatment is more efficient, economical and eco-friendly compared to the commercial available alum.

Keywords: Coagulants, Nephelometric, Turbidity, Alum, Crystals, Aluminum.

INTRODUCTION

Aluminum is the third most abundant element and most abundant metal in the Earth's crust. It is concentrated in a number of high grades, natural bauxite deposits[1]. Because of its low density, high tensile strength and resistance to corrosion, aluminum is widely used for the manufacturing of automobile products, aeroplanes, aluminum cans, and aluminum foils. Being good conductor of electricity, it is used for transmission for electricity. Aluminum is also found useful for making cooking utensils. The recycling of aluminum scraps is a very positive contribution in saving our natural environment and creating wealth. Most of the recycled aluminum are melted and recast into other aluminum metal products or

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used in the production of various aluminum compounds like alums in the form of dry crystals[2]. The alum has wide application in industries such as textile industry, waste water treatment plant, paper and pulp industry, food industry, domestic water purification; it is also medically used as an astringent and antiseptic, as a natural deodorant by inhibiting the growth of the bacteria responsible for body odor, to reduce bleeding in minor cuts and abrasions[2].

As pollution is increasing, the need for pollution free environment arises. Synthesizing potash alum from waste aluminum cans was found to be suitable for turning it into the useful chemical. The problem of environmental pollution by solid waste disposal is a major concern. Aluminum and other metals are environmental contaminants. Even the automobile now contains more aluminum alloys. Many food industries are on the increase in the use of aluminum foils[3].

The stimuli to recycle aluminum are thus very strong and are being reinforced by other recent developments. The production of aluminum from natural sources like bauxite (aluminum oxide, Al_2O_3) and cryolite (Na_3AlF_6) involves an electrolytic process which uses large amount of electricity and high cost of energy. The problem of recycling aluminum scraps and indiscriminate waste water disposal still pose a major challenge to environmental pollution agencies and to the populace[4]. Efforts are being made in the production of alum (coagulates) from aluminum scraps for waste water treatment and reduce pollution rate in the environment[2,5]. Due to competition in aluminum with calcium for absorption, the increased amount of dietary aluminum may contribute to the reduced skeletal mineralization (osteopenia) observed in infants with growth retardation. Aluminum can cause neurotoxicity, and is associated with altered function of the blood-brain barrier[6]. People who are allergic to aluminum and experience contact dermatitis, digestive disorders, vomiting or other symptoms upon contact or digestion of products containing aluminum, such as antiperspirants or antacids. Studies have shown that consumption of liquids with aluminum significantly increases aluminum absorption[7,8].

The objectives of this study were:

(a) Synthesize potash alum from waste aluminum scraps and used foils.

(b) Compare the physico-chemical properties of the synthesized coagulants to that of commercially available ones.

(c) Compare the efficiency of the synthesized alum to that of the commercially available coagulants in the treatment of waste water.

EXPERIMENTAL

Materials and methods

The chemicals and equipments used in this study were of analytical grade. The aluminum wastes (aluminum foil and aluminum scraps) were collected from homes and industries within Enugu metropolis, Nigeria. The collected materials were thoroughly washed with detergents and rinsed extensively with deionized water. The aluminum waste obtained was cut into smaller pieces. 1.15 g of the small pieces of aluminum waste was accurately weighed using analytical balance (model-HR-250A) into a beaker and then transferred to a hood. 250 mL of 1.4 M KOH solution was carefully added into the beaker containing the aluminum waste and heated, but not to boiling. The reaction is completed when the hydrogen evolution ceases and a clear solution appears without any visible pieces of aluminum metal. The solution was filtered under vacuum filtration (model-2019B-01) into a 500 mL flask and allowed to cool in a cooling bath.

250 mL of 4.0 M H_2SO_4 were carefully and slowly added to the flask containing the cooled solution. The solution was warmed gently after the addition of H_2SO_4 with stirring, until any $Al(OH)_3$ is completely dissolved. The reaction flask was kept into the ice bath to cool for 25 minutes. As the solution gets cool, 50 mL of 50 % ethanol/water mixture was cooled in the ice bath. The produced alum was recrystallized using the ethanol/water mixture. After drying for 2 days, the alum crystals were collected and weighed accurately using analytical balance (model-HR-250A) and the mass recorded. The overall reactions that takes place is as follows

$$2\ Al_{(s)} + 2\ KOH_{(aq)} + 4\ H_2SO_{4(aq)} + 22\ H_2O_{(l)} \xrightarrow{\Delta} 2KAl(SO_4)_2.12H_2O_{(s)} + 3H_{2(g)}$$

Chemical test for qualitative analysis of alum

Qualitative analysis of the synthesized potash alum was carried out to confirm the presence of potassium, sulphate, aluminum and water of hydration and the alum melting point.

Presence of water of crystallization on the synthesized alum

3.0 g of the alum was dried to a constant weight in a thermostatically automated oven and the weight difference was recorded. Alum is a hydrate, which means that it is a compound that has water molecules trapped within the solid. Hydrates will release some, or all of their waters of hydration upon heating[10]. One should expect that heating the alum will result in a decrease in the weight of the alum corresponding to the loss of 12 molecules of water per unit alum. The process by which the waters of hydration are driven off is described by the chemical equation shown below, where Δ above the arrow indicates that heat was applied to the reactant (s).

$$KAl(SO_4)_2.12\,H_2O_{(s)} \xrightarrow{\Delta} KAl(SO_4)_{2(s)} + 12\,H_2O_{(g)}$$

Efficiency of the synthesized alum to commercially available alum

Muddy water and waste water from fast food industry were used to check the efficiency of the synthesized alum. Distilled water was used in control experiment.

Two 20 mL of each water sample were measured in six separate test tubes labeled A, A_1, B, B_1 and C, C_1. The initial turbidity level of each water sample was recorded using digital turbidity (meter model no: 331). 0.50 g each of commercial alum and the synthesized alum were added into the different test tubes and left for three days. The synthesized alum was used in flask A, B, C while the commercial alum was used in flask A_1, B_1, and C_1. The turbidity of the sample waters were measured for both; the commercial and the synthesized alum after three days. The efficiency of the synthesized and commercially available alum was compared based on the turbidity measurement.

RESULTS AND DISCUSSION

The results of the experimental analysis were presented in the following tables:

Table 1: Yields of potash alum from aluminum wastes

Aluminum type	Mass of aluminum used (g)	Theoretical yield of alum (g)	Mass of alum obtained (g)	% Yield of alum
Aluminum foil	1.15	20.19	15.35	76
Aluminum scrap	1.15	20.19	12.74	63

Table 2: Determination of water of crystallization of the alum samples

Sample type	Initial mass of alum (g)	Final mass of alum (g)	% Water of crystallization
Alum from aluminum foil	3.0	1.65	45.0
Alum from aluminum scraps	3.0	1.66	44.7
Commercial alum	3.0	1.87	37.7

Table 3: Melting point determination of the alum sample

Sample type	Mass (g)	Melting point (°C)
Alum from aluminum foil	1.0	92
Alum from aluminum scraps	1.0	92
Commercial alum	1.0	97

Table 4: Determination of the turbidity of the water sample before addition of alum

Sample water type	Initial turbidity level (NTU)	Synthesized alum		Commercial alum	
		Final turbidity level (NTU)	% Reduction	Final turbidity level (NTU)	% Reduction
Muddy water	1839	169	90.8	221	88
Waste water from fast food	2305	34	98.5	74	96.8
Distilled water	0.00	2.0	-	3.0	-

NTU = Nephelometric turbidity unit

The results on the production of potash alum from aluminum foil as shown in Table 1 indicated that the mass of alum obtained from aluminum foil is 15.35 g and % yield of the synthesized alum was 76%. While the mass of alum obtained from aluminum scrap is 12.74 g, and % yield of the synthesized alum from aluminum scrap is 63%. From the results of the yields of alum from aluminum wastes, it is obvious that aluminum foil produced more alum than aluminum scrap under the same treatment. The aluminum scrap yields crystals of larger sizes than the crystals formed by the aluminum foil. The low yields of alum were possibly due to impurities present in the aluminum wastes as compared to the theoretical calculated yield of alum.

The presence of water of crystallization was indicated by the loss in mass of the alum crystals, when oven dried to dryness as shown in Table 2. The % water of crystallization of the synthesized alum was above 44% compared to the theoretical available % water of crystallization (45.57%) in alum, while that of commercial alum, it was below 38%. When drying, water within the span of 5-6 hrs, transformed into the salt with 6 molecules of water of crystallization while maintaining its powdery structure[9].

In Table 3, the physico-chemical analysis of the synthesized alum gave the same melting point at 92.0°C, whereas commercial alum gave 97.0°C. It is known that an alum crystal with 24 molecules of water and containing 45.57% of water, when subjected to heat, it melts rapidly at 92^{o}C-93^{o}C[9].

The physico-chemical analysis conducted shows that the synthesized alum crystal consist of potassium, aluminum, sulphate and water of crystallization with a molecular formula $KAl(SO_4)_2.12H_2O$. The composition of the synthesized alum shows that potassium, aluminum, sulphate, and water of crystallization are in the ratio of 1:1:2:12, respectively. The molecular weight of the synthesized alum [$KAl(SO_4)_2.12H_2O$] was calculated to be 474 g/mol by adding the atomic weight of each element present in the alum, which are in conformity with other double salt, to which alum belong. The synthesized alum shows similar qualities attributed to this class of salt[10]. Double salts ionize to produce three different types of ions in solution (two positively and negatively charged ions). From the synthesized alum, two positively charged ions (K^+ & Al^{3+}) and a negatively charge ion (SO_4^{2-}) were confirmed from the alum. The synthesized alum has large coagulating efficiency due to the large positively charged ions present in the alum, when dissolved in solution. These positively charged ions attract the negatively charged particles present in the water-thereby forming flocs, which then settles at the bottom of the water tank.

The turbidity level of each water sample measured (Table 5) before the addition of alum gave 1839 NTU and 2305 NTU for muddy water and waste water from a fast food industry, respectively. The distilled water sample was turbidity free before the addition of alum. This shows that waste water from fast food industry has higher level of impurity than the muddy water. This is because; they are contaminated differently by different species and at different degree. The stagnant muddy water is mostly contaminated by organic impurities. While the waste water from fast food industry were mostly contaminated with salts and coloured impurities and oils from food waste.

The efficiency of the synthesized alum and the commercially available alum were compared on the water samples (Table 4). After three days of addition of synthesized and commercial alum in distilled water, its turbidity level was measured as 2.0 and 3.0 NTU, respectively. The alum was meant to coagulate the colloids, colour and minerals that were suspended in the water. The addition of alum to the distilled water introduces impurities into the water and hence, the increase in turbidity after 3 days.

In muddy water, the initial turbidity level before the addition of alum gave 1839 NTU. After three days of addition of synthesized and commercially available alum, there was a drastic reduction of turbidity level from 1839 NTU to 169 NTU with 90.8% turbidity reduction on synthesized alum and to 221 NTU with 88% turbidity reduction on commercial alum. From the result, it is obvious that the synthesized potash alum is more effective in the treatment of dissolved and suspended particles in water than the commercially available alum.

In waste water from fast food industry, there was also a reduction in the turbidity level from 2305 NTU to 34 NTU with 98.5% turbidity reduction on synthesized alum and to 74 NTU with 96.8% turbidity reduction on commercially available alum. The synthesized alum also proves more effective in the treatment of waste water. From Table 4, it is observed that even when the waste water from fast food industry has more turbidity (2305 NTU) than the muddy water, which gave turbidity level of 1839 NTU. The waste water from fast food industry was more effectively treated to a reduced value of 34 NTU and 74 NTU by synthesized and commercial potash alum, respectively. This indicates that the muddy water have dissolved particles, which are more difficult to settle than that of waste water from fast food industry.

CONCLUSION

Alum crystals have been a sort after chemical because it's coagulating efficiency and ability to cause colloids, colour and mineral particles to agglomerate into settle-able flocs, in water purification and other industrial applications[10,11]. The demand of alum increases with increased awareness of purified water. Mineral water consumption has increased since the new millennium and there is enough demand for alum at each city as there are many small scale mineral water packaging plants. There are also great demands of alum in industrial sector. The use of alum is also applicable to cosmetics, pharmaceutical and agriculture. Synthesis of alum from aluminum waste is a sure way to solve environmental pollution problems in the society. Since, the use of synthesized alum has a greater efficiency; it is more effective and eco- friendly than the commercial alum in water treatment.

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