Ijeas Ideal Journal of Engineering and Applied Sciences 2(3) 146-151 Ijeas

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http://ijeas.truescholar.org

THE PRODUCTION OF ALUM USING ALUMINIUM SCRAP

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ABSTRACT

The recycling of aluminium cans and other aluminium products is a very positive contribution to saving our natural resources. Aluminium cans recycled by chemical processes that transform scrap aluminum into a useful chemical compound called potassium aluminum sulfate dodecahydrate, $KAl(SO_4)_2•12H_2O$, commonly called "alum" was observed in this study. The remains of fourteen (14) samples of beverage cans, foils and collapsible tubes were collected from an open hall immediate after social gathering in Warri, Delta State Nigeria. Also, nine (9) alum samples were bought from different markets location in Warri. Qualitative analysis for the alum purchased from the market were carried out by first reacting the alum with barium chloride in an aqueous solution, then the solution was reacted with potassium hydroxide before subjecting sample material to flame test. Qualitative Analysis of Aluminium Scarps was observed before determining the percentage composition of Aluminium in the scarps. The percentage composition of aluminium in the alum samples prepared from the aluminium scraps was determined and compared with the percentage composition of aluminium in the alum samples bought from the market. Results from this study reveal that the alum samples produced from the aluminium scrap had similar physicochemical property with those purchase from the market. This study further reveals that the cost of production of the alum samples produced from metal scarps appears uneconomically higher than those bought from the market. This was attributed to the high cost of consumable used in this study. Thus, considering the average life span of an aluminium can, this study do not only attempt to established that recycling has the benefit of reducing litter from discarded cans, neither do the process only saves 95% of the greenhouse gas emissions compared to the primary, or smelting, process, but it saves raw materials and reduces the space needed for landfill – where waste is buried in holes in the ground. There is therefore need for the federal government of Nigeria to make available stable power supply to its populace to reduce the cost of production of finished product starting from the raw materials needed for production process. This will go a long way to support small and medium scale enterprises and the establishment of petrochemical and other agro allied companies around the various refineries and will also; create decent employment opportunity for Nigerian.

KEYWORDS: Aluminium, Alum, Cans, Scrap, Qualitative, Quantitative, Recycle, $KAl(SO_4)_2•12H_2O$,

INTRODUCTION

Aluminium, because of its low density, high tensile strength and resistance to corrosion, is widely used for the manufacture of aeroplanes, automobiles lawn furniture as well as for aluminium cans. Being good conductor of electricity, it is used for transmission of electricity and for the making of utensils. The metal is a trivalent cation found in its ionic form in most kinds of animal and plant tissues and in natural waters everywhere (Jiang *et. al.,* 2008). It is the third most prevalent element and was reported by the Mount Sinai Hospital (2016) that it is the most abundant metal in the earth's crust, representing approximately 8% of total mineral components (verstraeten, 2008). Due to its reactivity, aluminium in nature is found only in combination with other elements. Dietary aluminium is ubiquitous but small quantity; it has no significant source of concern in persons with normal elimination capacity. Aluminium toxicity occurs when a person ingests or breathes high levels of aluminium into the body. Because aluminium is found in food, water, air, and soil, people may be possibly exposed to high levels of aluminium when they: drink or ingest substances containing high levels of aluminium, breath aluminium dust in workplace air, live where aluminium is mined or processed, live near certain hazardous waste sites and live where aluminium is naturally high. The aluminum Centers for Disease Control and Prevention (2015) and The Mount Sinai Hospital (2016) reported that diminished kidney function, hemodialysis, drinking or ingesting substances that are high in aluminium, living or working in an environment that contains high levels of aluminium and the living in dusty environments increases the chances of developing aluminium toxicity. They further reported that symptoms for kidney disease or dialysis may include: confusion, muscle weakness, bone pain, deformities, and fractures; seizures, speech problems and slow growth - in children. Complications may include: lung problems, nervous system problems causing difficulty with voluntary and involuntary actions Kawahara (2005); bone diseases Andia (1996); brain diseases and disorders, anemia and impaired iron absorption. Toxic effects of aluminium depend on the amount of metal ingested, entry rate, tissue distribution, concentration achieved, and excretion rate.

Verstraeten, (2008) reported that when significant aluminium concentration or load exceeds the body's excretory capacity, the excess is deposited in various tissues, including bone, brain, liver, heart, spleen, and muscle. This accumulation causes morbidity and mortality through various mechanisms. It is noticeable in the Niger Delta region and if not other part of Nigeria, in other part of the world that if not all, nearly every brand of an alcoholic and non alcoholic beverage, wine, juice, beer and other class of drinks are packaged in aluminium cans. General survey reveals that these liquid materials which could be classified as food is consumed by one of every two Nigerians every day. Also, good number of cosmetics such as facial creams product, skin lightener and medicated cream among other packaged with aluminium containers, are consumed by both the different class of teenage and adult. Due to the poor waste management facilities and culture in the Niger Delta region, coupled with poor policy to checkmate the indiscriminate dumping of refuse, and with no running recycling of waste materials plan on ground, aluminium scrap is dump in nearly every corner in the street, mostly in drainage obstructing the flow of flowing water thereby resulting to flooding during mild or heavy down pour, leaving visible stagnant water in the street (Okoh *et. al.*, 2016).

This could result to outbreak of disease such as cholera, dysentery and typhoid fever among others. This aluminium scrap could also be dumped and seen among heaps of refused in strategic locations on the streets, road side and in other organized refuse dump site across the Nigeria. Clinical survey reveals that aluminium level blood test is unreliable, as most of the body's stores are bound in bone and tissue and are not reflected in the serum value. The recycling of aluminium cans and other aluminium products is a very positive contribution to saving our natural resources. General survey in Nigeria reveals that beverages packed in aluminium cans popularly called “beverage cans” is potentially replacing those packed in glass bottles and has greatly reduced brutality resulting to fatality as a result of misunderstanding and conflict when drunk. The study owes its significance to the fact that beverage cans drinks, facial cream packed with aluminum tube and its likes presently dominates the Nigerian market especially in the Niger Delta Area of the country and the recycling aluminium scraps still pose a major challenge in Nigeria. Hence, the objective of this study is to produce alum using aluminium scarps from domestic wastes and the results compare with the concentration of alum purchase from an open market in Warri, in the Niger Delta region of Nigeria.

MATERIALS AND METHODS

Collection of Aluminium cans and alum samples

Good quantity of the remains of fourteen (14) samples of beverage cans, foils and collapsible tubes were collected several times from an open hall immediate after social gathering in Warri, Delta State Nigeria. Also, nine (9) alum samples were bought from different markets location in Warri. These samples were immediately taken to the laboratory for further analysis.

Preparation of Reagents

For the preparation of 2M KOH; To prepare 1000 mL of a 2 mol/L solution of KOH, we dissolved 112.2098 g of KOH pellet (formula weight is 56.105 g/mol) in deionized or distilled water, and then dilute the solution to the mark with deionized (distilled) water.

Also, 490cm^3 of concentrated H_2SO_4 (98% purify; 1.84gdm^{-3}) was measured and made up to 1 dm^3 with deionised water for the preparation of 9M H_2SO_4.

For the preparation of 0.0100M EDTA solution; approximately 2.92 grams of EDTA and dissolve it in 1dm^3 of deionized water and then, 20 g of 4% formaldehyde solution a Eiochrome - T indicator was added to the solution as indicator. This solution was then standardized using 0.0100M Magnesium Sulphate solution.

For 0.0100M magnesium sulphate: 4.92g of magnesium sulphate (Mol wt 246.473g) was weighed accurately, then dissolved in a 2 dm^3 flask and made up to the mark deionised water.

For the preparation of aluminium solution from the scraps; about 3.0 – 5.0g of each aluminium scrap (after removing the paint – coating and drying in oven) was weighed accurately and dissolved in 50% HCl in 250cm^3 standard flask. The solution was made up to the mark with deionised water.

Preparation of alum solutions: 1.18 - 1.19g each of the various alum samples was accurately weighed and dissolved with deionised water in a 250cm^3 standard flask and filled to mark. The resulting solution was approximately 0.01mole.

Solochrome Black Indicator: Solochrome black (Eriochrome black). The Ericochrome Black T indictor solution was prepared by dissolving 0.2g of the dye-stuff in $20cm^3$ of absolute ethanol.

Qualitative Analysis of Aluminium Scarps

The paint on can and collapsible tubes were removed with acetone, then washed with water and dried in the oven. The paints were removed to prevent interference with the cation to be analyzed. The cleansed aluminium scraps were cut in pieces of $1cm^2$. The pieces of the beverage cans and collapsible tube were placed in well labeled beakers where further analysis was carried out. Concentrated hydrochloric acid was introduced in the beakers containing the pieces of scraps, and the beakers were placed in fume chambers to avoid suffocation. The beakers were left with their content for 2-7 hours after which they were filtered. For the collapsible tube, light brown polythene called lacquer used in coating the inside of the tubes was removed by the acid after effervescence. The filtrate of each scarp was diluted with deionised water for further analysis.

Procedure of the Potash Alum Preparation

5g of the different collapsible tubes is put into a 500ml beaker. $200cm^3$ of 2M KOH is added into every beaker containing the different collapsible tubes. As part of precaution observed during this analysis, Open flame was not be allowed in the vicinity since explosion might occur as a result of hydrogen gas liberated during the reaction. The reaction took about twenty one (21) hour to complete. The reaction mixture was lift overnight and was thus filtered. On filtration, it was found that the filtrates were clear solution. $100cm^3$ of 9M H_2SO_4 was slowly added to every filtrate with stirred vigorously. The mixture produced a white paste which dissolves in the excess acid to give a clear and colourless solution. One - third of each solution sample was boiled off to concentration, covered with filter paper and was left to cool at room temperature for seventy two hour. On cooling, colourless crystal were observed at the bottom of the beaker. The colourless crystals found were washed with cold deionised water then dried in air and sun. The alum samples prepared were weighed as shown in (Table 1).

Determination of percentage composition of Aluminium in the scarps

The weight of the various aluminium samples was recorded and they placed in well labelled beakers. The aluminium scrap samples, in a fume chamber, were dissolved in concentrated HCl. Every dissolved scarp was diluted with $50cm^3$ deionised water. $25cm^3$ of the aluminium ion solution was then pipette into a conical flask, and $30cm^3$ in 0.0100M EDTA was run into the conical flask from a burette. Ammonia solution was then added (using universal indicator) to adjust the pH of the solution to a neutral point. The solution of different sample was boiled for a few minutes to ensure complete complexation of the aluminium. The solution was then cold to room temperature and the pH again was adjusted to 7 - 8. This is titrated rapidly with standard 0.0100M magnesium sulphate using solochrome Black T indicator. The colour change observed in all was from blue to wine red. The titre values of every aluminium scrap solution were recorded (Table 2)

Determination of percentage composition of aluminium in the alum samples prepared from the aluminium scraps

The different alum samples prepared were dissolved in deioned water. The 0.0100M EDTA and 0.0100M magnesium sulphate was used in the qualitative analysis. Solochrome Black T indicator was also used for the back titration. Procedure used is as that used above. The percentage of aluminium in the alum is as shown in Table 3

Determination of percentage composition of aluminium in the alum samples bought from the market

Samples of alum bought from the market were dissolved in deionised water to form a turbid solution. 0.100M EDTA and 0.010M Magnesium sulphate were used in the analysis with solo chrome Black T used as indicator. The percentage of aluminium in alum samples bought from the market is as shown in table 4

Qualitative Analysis of Alum Purchased from the Market

For the qualitative test, alum crystals were transferred into a test – tube with the aid of a scapular where they were dissolved in few drops of water. After ensuring that all the alum dissolved, one or two drops of 0.5 M $BaCl_2$ solution were added to the alum solution in the test tube and the observations recorded. Further analysis was performed to confirm the presence of potassium with the flame test before subjecting the alum to test that confirms the presence of aluminum ion

RESULTS AND DISCUSSIONS

Results

Table 1 – 4 shows the weight of Al scrap consumed and the quantity of alum produced, the percentage of aluminium in the aluminium bearing scarps, the percentage of Aluminium in the Alum Prepared from Aluminium Scarps and the Percentage of aluminium in the alum samples bought from the market.

Table 1: The weight of aluminium scraps consumed and the yield of Alum produced

Aluminium Scrap	Weight of scrap used (g)	Weight of alum produced (g)
Holdent	5	73.12
Perfect Finish	5	76.29
Neutrogel	5	69.47
Fair & Beautiful	5	72.67
Canex cream	5	67.90
Nizoral	5	62.94
Delident	5	37.22
Visible different	5	67.40
Zarina	5	70.44
Skin success	5	68.86
Aluminium foil	5	53.54
Nexodem	5	75.49

Table 2: Percentage of aluminium in the aluminium bearing scarps

S/N	**25cm^3 of Al^{3+}**	**Average titre value (cm^3) A**	**EDTA Volume (cm^3) (V)**	**Difference of (V - A)**	**Weight(g) of Al in Al^{3+}**	**Weight (g) of scarp dissolved**	**% Aluminium Scarp**
1	Holdent	4.40	30.00	25.60	0.0691	0.0698	99.00
2	Perfect finish	4.20	30.00	25.80	0.0696	0.0698	99.71
3	Neutrogel	5.40	30.00	24.60	0.0698	0.0968	96.80
4	Fair & beautiful	4.80	30.00	25.20	0.0680	0.0696	97.70
5	Canexcream	6.70	30.00	23.30	0.0629	0.0636	98.90
6	Nizoral	7.10	30.00	22.90	0.0618	0.0641	96.41
7	Delident	6.90	30.00	23.10	0.0623	0.0669	93.12
8	Visible difference	7.80	30.00	22.20	0.0599	0.0676	88.61
9	Benetovate– N	5.80	30.00	24.20	0.0653	0.0668	97.76
10	Zarina	5.50	30.00	24.50	0.0661	0.0671	98.51
11	Fair & white	5.95	30.00	24.05	0.0649	0.0656	98.93
12	Skin success	7.20	30.00	22.08	0.0615	0.0657	93.61
13	Alumiunium foil	7.40	30.00	22.60	0.0610	0.0668	91.32
14	Nexodem	6.10	30.00	23.90	0.0645	0.0651	99.08

Table 3: Percentage of Aluminium in the Alum Prepared from Aluminium Scarps

S/N	Al Scraps	Colour of Alum produce	Colour of solution	Average titra value (cm^3)A	EDTA Volume (cm^3) (V)	Difference (cm3) (V-A)	Weight (g) of Alum	Weight (g) of Al	% of Al in Alum
1	Holdent	Colourless	Colourless	8.40	30	21.66	1.077	0.5823	5.41
2	Perfect finish	Colourless	Colourless	8.34	30	21.66	1.045	0.05844	5.59
3	Neutrogel	Colourless	Colourless	9.20	30	20.30	1.146	0.05612	4.90
4	Fair and beautiful	Colourless	Colourless	8.80	30	21.20	1.343	0.05720	4.26
5	Cenexcream	Colourless	Colourless	10.70	30	19.30	0.875	0.05207	5.95
6	Nizoral	Colourless	Colourless	11.10	30	18.90	1.069	0.05207	5.95
7	Delident	Colourless	Colourless	13.90	30	16.10	1.050	0.04343	4.14
8	Visible difference	Colourless	Colourless	12.00	30	18.00	1.115	0.04856	4.35
9	Benetovate –N	Colourless	Colourless	9.90	30	20.10	1.139	0.05422	4.76
10	Zarina	Colourless	Colourless	9.50	30	20.50	1.311	0.05531	4.22
11	Fair and white	Colourless	Colourless	9.50	30	20.50	1.311	0.05531	4.22
12	Skin success	Colourless	Colourless	11.20	30	18.10	1.185	0.04883	4.12
13	Aluminium foil	Colourless	Colourless	11.40	30	18.30	1.312	0.04937	3.76
14	Nexodem	Colourless	Colourless	8.20	30	21.80	1.308	0.05882	4.50

Table 4: Percentage of aluminium in the alum samples bought from the market

S/N	Al sample	Colour of alum	Colour of alum in solution	Average titre value (cm^3) A	EDTA Volume cm^3 V	Diff cm^3 (V-A)	Wt (g) of alum sample used	Wt (g) of alum sample	% Al scrap
1	S_1	White	Turbid	3.00	30	27.00	1.2423	0.0725	5.84
2	S_2	White	Turbid	2.50	30	27.50	1.3400	0.0742	5.54
3	S_3	White	Turbid	2.40	30	27.60	1.2373	0.0745	6.02
4	S_4	White	Turbid	1.50	30	28.50	1.2335	0.0769	6.23
5	S_5	White	Turbid	1.10	30	28.90	1.2813	0.0780	6.09
6	S_6	White	Turbid	1.30	30	28.70	1.2361	0.0774	6.26
7	S_7	White	Turbid	1.05	30	28.95	1.2439	0.0781	6.28
8	S_8	White	Turbid	2.00	30	28.00	1.2111	0.0755	6.23
9	S_9	White	Turbid	1.05	30	28.95	1.2690	0.0781	6.16

Average % 6.07±.22

DISCUSSIONS

Alums are ionic compounds that crystallize from solutions containing sulfate ion, a trivalent cation such as Al^{3+}, Cr^{3+}, or Fe^{3+} and a monovalent cation such as K^+, Na^+, or NH_4^+. Six of the water molecules bind tightly to the trivalent metal ion; the remaining six molecules bind more loosely to the monovalent cation and the sulfate anion. This compound is widely used in dyeing fabrics, making pickles, making paper and purifying water. Although aluminum metal sits well above hydrogen in the activity series, it reacts only slowly with dilute acids because a thin coating of aluminum oxide protects the metal surface. Aluminum reacts with alkaline solutions to produce hydrogen gas because the excess hydroxide ion first attacks the tough Al_2O_3 layer so the metal can react. Aluminum converts to the tetrahydroxoaluminate ion $Al(OH)_4^-$ The slow addition of acid to the solution of this ion results to the precipitation of solid $Al(OH)_3$ followed by the dissolving of the precipitate to form the Al^{3+}. The solid $Al(OH)_3$ will also dissolve in excess base due to the formation of $Al(OH)_4^-$. Below is the equation for the reaction.

The dissolution step

Reaction of aluminum with KOH

$$2Al_{(s)} + 2KOH_{(aq)} + 6H_2O_{(l)} \rightarrow 2KAl(OH)_{4(aq)} + 3H_{2(g)}$$

The precipitation step

Initial addition of sulfuric acid

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

The dissolving of $Al(OH)_3$

Further addition of sulfuric acid

$$2Al(OH)_{3\ (s)} + H_2SO_{4\ (aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 6H_2O_{(l)}$$

Precipitation of alum on cooling

$$K_2SO_{4(aq)} + Al_2(SO_4)_{3(aq)} + 24H_2O_{(l)} \rightarrow 2\ KAl(SO_4)_2 \cdot 12\ H_2O_{(s)}$$

It is possible to write an overall net ionic equation for the precipitation process:

$$K^+_{(aq)} + Al^{3+}_{(aq)} + 2SO_4^{2-}{}_{(aq)} + 12H_2O_{(l)} \rightarrow KAl(SO_4)_2 .12H_2O_{(l)}$$

Crystals of the double salt $KAl(SO_4)_2.12H_2O_{(s)}$, or alum, was form upon cooling the final solution since the solubility of alum in water decreases as the temperature is lowered.

Qualitative Analysis of Scraps

The result from the qualitative analysis of the aluminium scrap reveals that all metal samples under investigation contains aluminium metal and trace amounts of iron (ii) and other impurity which range from 1 – 11.39%. This explains the reason why the data's obtained in table 2 for the various aluminium scrap are not 100%. The average percentage of the aluminium obtained from the scraps used was 96.00 ± 0.16%.

Qualitative Analysis of Alum Produced

The precipitation of $BaSO_{4(s)}$ from the alum solution upon the reaction with barium chloride gave a positive test for the presence of SO_4^{2-} as shown by the equation below. $KAl(SO_4)_{2(aq)} + 2BaCl_{2(aq)} \rightarrow 2BaSO_{4(s)} + KAlCl_{4(aq).}$ Further analysis using the flame test reveals that potassium is volatilized at a very high temperature of a flame of about 1000°C with a bluish – purple colour. Few seconds into the flame, $SO_{2(g)}$ were given off from the alum sample. The presence of aluminium was confirmed when potassium hydroxide was added to the alum solution. A wispy, gelatinous precipitate of $Al(OH)_3$ was form in drop which dissolve in excess KOH.

Analysis of Alum Samples

The physical properties of the alum samples prepared from aluminium scarps were not the same with alum purchased from the market. Two type of alum were basically used for this study – those with average % aluminium as 5.62 ± 0.07 and those with % aluminium as 6.07 ± 0.22. The slight difference in % aluminium present in the alum sample produced in this study and the alum purchased from the market might be due to the fact that the market samples were product of industrial processes with varying quality control process.

Comparative Costing of Alum Prepared from Scarp and Alum bought from market

The cost of production of the alum samples produced from metal scarps appears uneconomically higher than those bought from the market. This is attributed to the high cost of analytical grade chemicals for potassium hydroxide and tetraoxosulphate (vi) acid. In other words, the prices of laboratory chemicals are usually very much higher than the prices from industrial chemicals. This fact could be attributed to the lack of petrochemical industries as large amount of all chemicals brought into Delta State Passes through a chain of complex transportation network which thus increases the cost of the chemicals.

CONCLUSION

Though, modern beverage containers are usually composed of mainly aluminum, in the form of aluminum cans, Aluminum is one of the most indestructible materials used in metal containers. Considering the average life span of an aluminium can, this study do not only attempt to established that recycling has the benefit of reducing litter from discarded cans, neither do the process only saves 95% of the greenhouse gas emissions compared to the primary production or smelting process, or do it saves raw materials and reduces the space needed for landfill – where waste is buried in holes in the ground

(Think cans, 2012), but the process also use a chemical process to transform aluminium scrap into a useful chemical compound - potassium aluminum sulfate dodecahydrate, $KAl(SO_4)_2 \cdot 12H_2O$, commonly called "alum". Finding from this study reveals that the cost of production of the alum samples produced from metal scarps appears uneconomically higher than those bought from the market. It is thus recommended that the federal government of Nigeria should produce stable power supply to its populace to reduce the cost of production of finish products and the basic raw materials needed for production process. This will go a long way to support small and medium scale enterprises and the establishment of petrochemical and other agro allied companies around the refineries. This step will not only reduce the rate of unemployment, but it will also enhance the mean advantages of economics of scale and the commercial success of production of the alum.

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