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Alum from Waste Beverage Cans: An Environmental Friendly Approach

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Abstract: *Aluminum is one of the widely used materials in packaging industry either in the form of cans or in form of linings. In this research work, we have used waste beverage cans and recycled them using crystallization unit operation to convert raw cans into useful alum. Swenson Walker is one of the most effective and the newest technology used in waste recycling into crystals. The whole experiment was carried out in a pilot laboratory scale Swenson walker crystallizer and a percent recovery of 95% octahedron shaped crystals was found. A cost analysis of total cost was done and a profit of twenty rupees per 76 gm of crystals was obtained.*

1. INTRODUCTION

Aluminum recycling has increased steadily since 1970, with recycled aluminum becoming a much more important source of supply over the period. The quantity of aluminum recycled in 1989 was slightly more than 2.0 million metric tons, which is more than twice that recycled in 1970.

Increased used beverage cans recycling have fueled this increase in overall recycling. Aluminum cans are lightweight, convenient, portable, and keep beverages cold. They are often used to package soda, beer, and other beverages, and account for nearly all of the beverage packaging market for some products. The Aluminum Association and the Can Manufacturers Institute have reported that the UBC recycling rate rose from 26.4 percent in 1977 to 60.8 percent in 1989. In 2012, the United States generated about 1.9 million tons of aluminum as containers and packaging. About 1.7 million tons of aluminum was used to make durable and nondurable goods, such as appliances and automobile parts.

Modern beverage containers are usually composed of either aluminum, in the form of aluminum cans, or polyethylene terephthalate (PETE), the clear plastic beverage bottles. Approximately 300 million aluminum beverage cans are produced each day in the U.S. Aluminum is one of the most indestructible materials used in metal containers. The average life of an aluminum can is about one hundred years et. Al. David.

Crystallization is one of the recent research area found to increase these recycling process. It is the natural or artificial process of formation of solid crystals precipitating from a solution. This operation involves both heat and mass transfer. Attempts to model crystal growth mathematically have fared little better; they often fail to predict either the commonly observed lognormal size distribution or the associated crystal size variance (Eberl et al. 2002a). All of the geometrically similar crystals in a system, regardless of their size, will grow by the same linear amount (i.e., add a layer of material with the same thickness) during a given time interval. The origin of this type of growth has been ascribed to several crystal growth mechanisms, including surface-reaction-limited polynuclear growth and spiral growth (Nielson1964; Ohara and Reid 1973; Nordeng and Sibley, 1996). These mechanisms are consistent with classical spiral crystal growth theory as described by Burton, Cabrera and Frank (i.e., the BCF model as described in Bennema 1967, 1984), The constant growth law has been the foundation of many attempts to model crystal growth; it underlies the population balance equation used in petrology (e.g., Marsh 1988), the growth models proposed by Kretz (1966), the classic Johnson, Mehl, and Avrami (JMA)approach (discussed in Kirkpatrick 1981), and the population balance model proposed by McCoy (2001), among others. However, there is a growing body of literature that contradicts the constant growth law. Proportionate growth, evidenced in both natural and synthetic crystal systems, appears to better account for observed CSDs, and has been found in a variety of synthetic crystal systems studied by Canning and Randolph (1967), Mullin and Gaska (1969), Garside and Jancic (1976), Jones et al. (1986), Tai and Yu (1989), and Tai et al. (1993). The Swenson-walker crystallizer is a cooling type, continuous, jacketed trough crystallizer. It is an example of the scrapped surface crystallizer and is probably most widely used crystallizer.

2. METHODOLOGY

In this paper we have adopted a new methodology in which instead of recycling the aluminum of waste cans into new cans; we actually recycled this scrap aluminum into useful alum which in chemical literature is known as potassium aluminum sulfate dodecahydrate, $KAl(S0_4)_2 \cdot 12H_20$.

2.1 Reaction Chemistry

In the recycling process two chemical compounds namely potassium hydroxide and sulfuric acid are used in very small quantity relative to the product formed. Potassium hydroxide dissolves the oxide layer with evolution of hydrogen and then attack the metal David A. Katz et.al.

Thus, with the reaction of potassium hydroxide with the metal, the aluminum is oxidized to the tetra-hydroxoaluminate (III) anion which is stable only in basic solution.

$$2\ A1(s) + 6\ H_2O(l) + 2\ KOH(aq) \dashrightarrow 2\ K[Al\ (OH)_4](aq) + 3\ H_2(g)$$

When sulfuric acid is slowly added to an alkaline solution of this complex anion, initially, one hydroxide ion is removed from each tetra-hydroxoaluminate anion causing the precipitation of white, gelatinous aluminum hydroxide.

$$2K[Al(OH)_4](aq) + H_2SO_4(aq) \dashrightarrow 2\ Al(OH)_3(s) + K_2SO_4(aq) + 2\ H_2O(l)$$

The excess potassium hydroxide is neutralized by some of the sulfuric acid to form potassium sulfate.

$$2\ KOH(aq) + H_2SO_4(aq) \dashrightarrow K_2SO_4(aq) + 2\ H_2O(l)$$

On addition of more sulfuric acid, the aluminum hydroxide dissolves forming the hydrated aluminum cation.

$$2\ A1(OH)_3(s) + 3\ H_2SO_4(aq) \dashrightarrow Al_2(SO_4)_3(aq) + 6\ H_2O(l)$$

Addition of alkali to the $Al(OH)_3$ precipitate will also bring about dissolution by reforming $[Al(OH)_4]^-$.

When the acidified aluminum sulfate solution is cooled, potassium aluminum sulfate do-decahydrate i.e. Alum precipitates.

$$A1_2(SO_4)_3(aq) + K_2SO_4(aq) + 24\ H_2O(l) \dashrightarrow 2\ K[Al(SO_4)_2] \cdot 12H_2O(s)$$

The overall reaction that takes place is the sum of the previous reactions.

$$2\ Al(s) + 2\ KOH(aq) + 4\ H_2SO_4(aq) + 22\ H_2O(l) \dashrightarrow 2\ KA1(SO_4)_2 \cdot 12H_2O(s) + 3\ H_2(g)$$

2.2 Process Description

The aluminum cans were collected from various waste stores/ canteens and from door to door collection. These collected cans were first cut into pieces of sufficient length with the help of a cutter so as to remove the main aluminum body from the lid, neck and the hard base of the can.

Now a thorough scrapping of the aluminum body is done to remove the label, paint and any extraneous matter from the cans. These cleaned pieces were weighed and further cut into very small pieces of almost 1 cm x 1 cm in size. These small pieces will be easier to dissolution. Figure 1 shows the small cut pieces of cans.

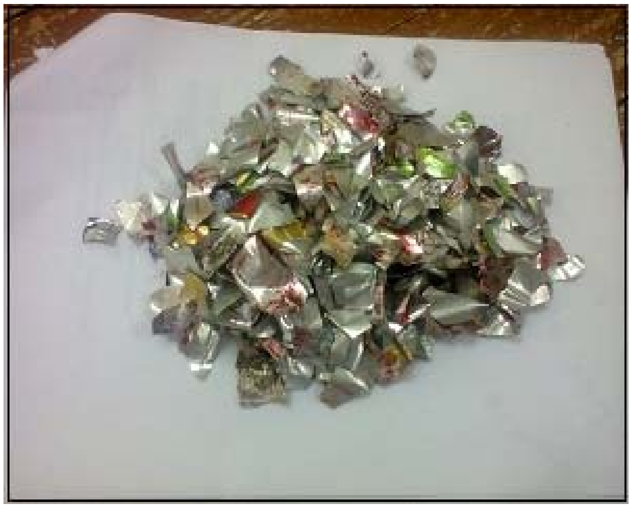

Fig. 1: Small cut pieces of cans

These pieces were now weighed and transferred to a 1.4 M KOH solution and then to the Swenson walker crystallizer's heater tank in a sufficient quantity to make the solution supersaturated as this works as the driving force for crystallization.

Fig. 2: Pictorial view of Swenson Walker Crystallizer

In the pilot scale Swenson walker crystallizer two tanks are provided at the bottom. One is the cooling water tank and the second is a tank incorporated with a heater to heat the required supersaturated solution. The quantities of various material and chemical compounds are tabulated in table 1.

Table 1: List of Material Used

MATERIAL	QUANTITY
Pieces of aluminum from cans	80 gm
1.4 M KOH	2 liter
9 M Sulfuric acid	350 ml

The heater is kept on at a duty of 1 KW such that the solution achieves a higher temperature but do not boils. It was observed that bubbles of hydrogen gas were formed and this heating was continued until this bubble formation ceases with time.

As soon as the bubbles formation stops it indicate that no more hydrogen is further present in the solution and we got a dark black colored solution along with the remaining pieces un converted aluminum pieces.

Now this solution is filtered so as to discard any plastic or un reacted metal remaining and a very clear solution is obtained as the filtrate. This solution is cooled to room temperature and was now transferred to the main tank of Swenson walker crystallizer with the help of a pump. Cool chilled water was filled in the cooling tank of the crystallizer and it was circulated thoroughly to the jacket provided and the agitator was started at this moment. Now slow cooling of the solution with agitation at a speed of 2 rpm was done. The process operating conditions are tabulated in table 2.

Table 2: Operating Conditions

PARAMETERS	VALUE
Heater duty	1 KW
Cooling water temperature	18 C
Agitator speed	2 rpm
Cooling water flow rate	3 l/min

With this cooling a slow addition of 9 M H_2SO_4 was done to neutralize the reaction occurring, this is slightly exothermic reaction. A white precipitate of aluminum hydroxide was observed. Addition of the last few milliliters of the sulfuric acid usually dissolve the $Al(OH)_3$.

Crystal of alums was observed to begin within 15 minute of the reaction. When the steady state process was observed to be completed the solution containing crystals was drained from the bottom through a screen into a collecting tank.

The final crystal obtained were dried and weighed.

3. RESULTS AND DISCUSSION

3.1 Size and Shape of the crystals Obtained

The crystallization process consists of two major events, nucleation and crystal growth. Nucleation is the step where the solute molecules dispersed in the solvent start to gather into clusters, on the nanometer, that become stable under the current operating conditions. These stable clusters constitute the nuclei. However, when the clusters are not stable, they dissolve.

In this experimental work it was observed that a stable nucleation prevails at about 7 minutes after the cooling started along with the addition of sulfuric acid.

The crystal growth is the subsequent growth of the nuclei that succeed in achieving the critical cluster size. Depending upon the conditions, either nucleation or growth may be predominant over the other, and as a result, crystals with different sizes and shapes are obtained.

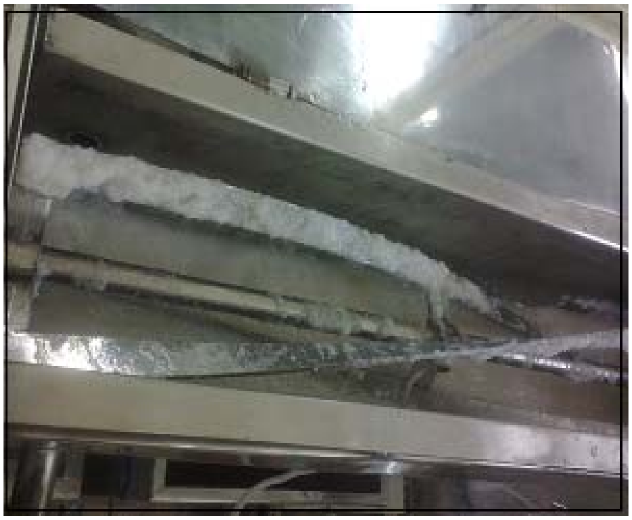

Fig. 3: Crystal growth in crystallizer

In our experiment it was observed that after a 30 minute period of time the crystal growth suddenly predominates and alum crystal of different size were obtained.

Fig. 4: The final wet crystal product of alum

These crystal are then dried and a final weight of dried crystal was taken which weighs 76 gm.

Fig. 5: Dried alum crystal

It was observed that the shape of the crystal is found to be of octahedron type. Crystal size for alum was determined by considering average length of the crystal obtained which was found to be between 1.5 to 3 cm.

3.2 Percent Recovery

Percent recovery is defined as the amount of pure substance obtained from the initial impure substance.

$$\text{Percent Recovery} = \frac{\text{Amount of pure substance recovered}}{(\text{Amount of initial impure substance})}$$

Amount of alum crystals formed = 76 gm
Amount of aluminum chips taken = 80 gm

$$\text{Percent Recovery} = \left(\frac{76}{80}\right) * 100$$

Therefore, Percent recovery = 95 %

3.3 Theoretical Yield of the Alum:

Theoretical yield = Mass of aluminum used *

$$\left(\frac{\text{1 mole aluminum}}{\text{atomic weight aluminum}}\right) * \left(\frac{\text{mole of alum produced}}{\text{moles of aluminum used}}\right) * \left(\frac{\text{formula weight of alum}}{\text{1 mole alum}}\right)$$

Theoretical yield = 80 * (1/26.98)*(0.294/2.96)*(474/1)

Theoretical yield = 38%

According to reaction

2 moles of aluminum will react to form 2 moles of alum.

Formula weight of alum = 474 g/mole

Atomic weight of Aluminum = 26.98 amu

Moles of alum produced = (weight/ Molecular weight) = 76/258= 0.294

Moles of Aluminum used = 80/26.98= 2.96

Mass of aluminum used = 80 gm

3.4 Economic and Environmental Impact Analysis

The aluminum can as purchased from the waste store was at a cost of five rupees however the alum crystal so formed i.e. 76 gm alum crystal cost in the market as twenty five rupees, which means a direct profit of twenty rupees was gained. However above and all the waste is no more a waste but was converted into a useful product which help in various applications such as dyeing of fabrics, in the manufacture of pickles, in canning some foods, as a coagulant in water purification and waste-water treatment plants, and in the paper industry.

4. CONCLUSION

Aluminum is one of the most indestructible materials used in metal containers. The major source of aluminum waste is the used beverages cans. These can be recycled into useful alum using crystallization process. Crystallization is the natural or artificial process of formation of solid crystals precipitating from a solution. Swenson Walker crystallizer is the most efficient scrapper surface crystallizer which includes facility of heating as well as jacketed cooling system. We have recycled Around ten cold drinks cans which gives 80 gm aluminum using this process and obtained 76 gm of octahedral alum crystals of length ranging between 1.5 to 3 cm. The percent recovery was 95% while the yield of crystals was 35%. A gain of twenty rupees/ 76 gm of alum crystal was obtained. Crystallization using Swenson walker was found better over the conventional laboratory method in terms of percent recovery and yield obtained.

5. REFRENCES

[1] Kloprogge J.T., Geus J.W., Jansen J.B.H., Seyken D. "Thermal stability of basic aluminum sulfate", *Thermoc. Acta.* 1992, Vol. 209, pp: 265–276.

[2] Bhattacharya I.N., Gochhayat K., Mukherjee P.S., Paul S., Mitra P.K, "Thermal decomposition of precipitated low bulk density basic aluminum sulphate",. *Mater. Chem. Phys.* 2004, Vol. 88, pp: 32–40.

[3] Smith R.L., Rohrer G.S., Perrotta A.J., “Influence of diaspore seeding and chloride concentration on the transformation of “Diasporic” precursors to corundum”. *J. Am. Ceram. Soc.* 2001, Vol. 84, pp: 1896–1902.

[4] Shackelford J.F., Doremus R.H, “Ceramic and Glass Materials: Structure, Properties and Processing”, *Springer*, 2008.

[5] Tijburg I.I.M., Bruin H.D., Elberse P.A., Geus J.W. “Sintering of pseudo-Boehmite and γ-Al_2O_3”, J. *Mater. Sci.* 1991, Vol. 26, pp: 5945–5949.

[6] Loong C.K., Richardson J.W., Ozawa M., “Structural phase-transformations of rare-earth modified transition alumina to corundum*”,. J. Alloy. Compd*. 1997, Vol. 250, pp: 356–359.

[7] Mekasuwandumrong O., Tantichuwet P., Chaisuk C. “Impact of concentration and Si doping on the properties and phase transformation behavior of nano crystalline alumina prepared via solvothermal synthesis”, *Mater. Chem. Phys*. 2008, Vol. 107, pp: 208–214.

[8] Bowen P., Carry C, “From powders to sintered pieces: Forming, transformations and sintering of nanostructured ceramic oxides”, *Powder Technol*. 2002, Vol. 128, pp: 248–255.