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Production of Alum from Aluminium Drink Cans Waste for Water Treatment

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Abstract

The graphite furnaces atomic absorption spectrophotometry (GFAAS) technique has been previously used to quantify the aluminium (Al) content in soft drinks made from aluminium cans over the course of a 12-month storage period. The current research aimed to determine the efficacy of alum obtained from waste soft drink cans compared to the alum obtained from local markets in treating water from Shatt al-Arab, Basrah, Khorramshahr, and Abadan, Iraq. The Shatt al-Arab Treatment Plant in Basra governorate is the subject of the investigation. A raw water sample was taken from the water treatment facility at the Basra governorate (Shatt al-Arab water), and household aluminium waste soft drink cans were obtained from scavengers in the Basra neighbourhood. The extraction of alum from domestic aluminium wastes was done in a lab experiment. Required statistical analysis was done, and a comparison was made. The study showed the volume of water was equal (350 ml) in both samples before coagulation but was slightly high in the standard article (320 ml) after coagulation. The water turbidity is the same in both groups before coagulation and greatest in standard after (82 NTU) coagulation. The solids are highly dissolved in the standard group (258 ppm) after coagulation than prepared (170 ppm). The prepared material shows high conductivity (20) than the standard (15.59). The prepared material is highly acidic (1.2 pH), with high calcium (160 mg/l), sulfate (2720 mg/l), potassium (525.6 mg/l), sodium (132.66 mg/l), and low chloride (2130 mg/l), and magnesium (92.34 mg/l) compared to standard material from the market. The study concludes that there are no relevant differences in using the alum that is available in markets for the same purpose and that is prepared.

Keywords: Alum, water treatment, aluminium, wastewater, water quality

INTRODUCTION

The graphite furnaces atomic absorption spectrophotometry (GFAAS) technique has been previously used to quantify the aluminium (Al) content in soft drinks made from aluminium cans over the course of a 12-month storage period. The findings indicate that throughout the whole storage period, the Al content of all soft beverages increased [1–3]. This rise was brought on by the dissolving of aluminium from the can wall brought on by the aggressive chemicals, primarily acids, present in soft drinks. As the acid concentration climbed and the pH of the soft drinks dropped, the Al content increased. In comparison to the recommended daily intake as well as the total amount of Al consumed each day, the estimated daily intake of Al (0.9 mg) from these drinks was almost minimal [1,4].

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A study describes a recycling effort that used aluminium cans to make Al_2O_3 because no similar work has been documented in the literature [5] $Al_2(SO_4)_3$ solution was created by combining heated aluminium cans with 8.1 M of H_2SO_4 solution. The $Al_2(SO_4)_3$ salt was suspended in a white, semi-liquid solution that contained too much H_2SO_4 and some unreacted aluminium particles

[6,7]. After filtering, the solution was combined in a 2:3 ratio with ethanol to create a white solid of $Al_2(SO_4)_3.18\ H_2O$. $Al_2(SO_4)_3.18\ H_2O$ was calcined for 3 hours at 400–1400 °C in an electrical furnace. Ten degrees Celsius each minute were heated and cooled. The phase shifts at various temperatures were investigated using XRD, and the elemental makeup of the generated alumina was ascertained using XRF. The $Al_2(SO_4)_3.18\ H_2O$ was repeatedly dehydrated and desulfonated to produce a variety of various alumina compositions. At high temperatures, all transitional alumina phases created at low temperatures were changed into Al_2O_3. The Al_2O_3 phase was realised when the calcination temperature was at 1200°C or higher, according to the X-ray diffraction data [8–14].

Physical and chemical characteristics of the hazardous aluminium solid waste samples, such as dross, were determined. The density, porosity, and metal content of the dross were shown to be correlated [15,16]. The essay also looks at the detrimental effects of aluminium dross landfill chemical processes [17]. A processing technique was created to recover the aluminium and prevent environmental issues, and the aluminium was recovered as a product with added value, such as alumina [18]. This process, which includes acid leaching, filtration, precipitation, and calcination, takes place at low temperatures. Aluminium was extracted at the end of this procedure, first as Al^{3+} soluble ions and then as an alumina product [19].

Leaching experiments were employed to highlight the composition of the produced aluminium dross and alumina powder using atomic absorption spectrometry (AAS) and chemical analysis. SEM was used to characterise the morphology of samples of aluminium dross and an alumina product, and X-ray diffraction (XRD) was used to assess their mineralogical composition (SEM). Using the technique described in this paper, it is possible to produce high-grade, pure alumina from the hazardous aluminium solid waste by recovering a significant portion of its soluble aluminium content [20–22].

Aims of the Study

1. To analyse the alum found in the waste cans and alum found in the local market
2. To find out the efficacy of alum obtained from waste cans and local markets in treating wastewater.

Questions of the Study

1. Whether the alum found in the waste can be used in treating the water by decreasing its turbidity?
2. Does the alum obtained from waste cans effective as an alum from the local market in wastewater treatment?

Significance of the Study

The study brought forward a research finding which shows that the alum which is prepared from the waste cans is similarly effective as the alum found from the local market in treating wastewater. The statistical analysis showed that there is no significant difference between the alum obtained from the local market and the prepared one. But from an economic aspect, the alum obtained from waste cans is significantly less costly than that of alum obtained from the market. Therefore, the whole process can be done much more economically.

LITERATURE REVIEW

A study conducted illustrated how water treatment facility alum sludge might be transformed into high-quality zeolite LTA. This may help to prevent issues with sludge land expenses and environmental contamination. To increase the production of both high-quality and high-quantity zeolite LTA, alum sludge was first subjected to an alkali fusion pre-treatment before being subjected to hydrothermal synthesis. High-quality zeolite LTA that was equivalent to commercially available material and greater to samples created using hydrothermally synthesised without fusion pre-treatment was made possible by alum sludge activation utilising fusion. Notably, the samples made from alum sludge had higher

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levels of contaminants such as iron, magnesium, and calcium. The work has shown that high-quality zeolite LTA may be manufactured from alum sludge left over from drinking water treatment facilities [6, 23, 24].

Alum sludge is one of the global issues connected to the generation of potable water when aluminium sulphate ($Al_2(SO_4)_3.18\ H_2O$) is employed as a coagulant. Every year, water operators in Malaysia produce more than 2.0 million tonnes of water purification sludge or residue (WTS). It is crucial to understand that the creation of alum sludge may continue to be inevitable in the processing of water treatment technologies as they are now implemented. Researchers are seeking new alternatives to traditional materials like cement, ceramic, bricks, tiles, and aggregates in order to reduce the impact of this waste on the environment and to meet disposal of waste criteria set by the local/federal authority [7, 25].

A study conducted to assess offers a chemical method for turning used aluminium cans into alum crystals, which has several uses in modern industry. Concentrated acidic and alkaline solutions with the main ions K^+ and SO_4^{2-} were used to conduct the study. Aluminium cans were dissolved in KOH solution, neutralised with H_2SO_4 solution, and then crystallised while cooling to provide alum crystals. The % yield of alum and aluminium recovered from used aluminium cans to valuable products was highlighted. When 5 g of aluminium beverage cans were combined with 1.5 M of KOH solution and 9 M of H_2SO_4 solution, the result had a maximum yield of 80%. The yield of alum synthesis increased together with the concentration of KOH and H_2SO_4 solution. It was discovered that recycling aluminium from used beverage cans into alum using the crystallisation process was successful [8, 26, 27]

A systems analysis has been carried out to see whether it is feasible to recycle all of the trash produced by water treatment facilities. Actual wastewater and alum sludge utilised in this study were gathered from a water treatment facility using methods like filtration, pH correction, fluoridation, and chlorination after aeration, chemical addition, mixing, flocculation, and sedimentation. The sediment basin, as well as the filter backwash, is the main source of wastewater and sludge production. The waste recycling process under study involved (a) treating the filtration backwash water in a sludge separator, (b) separating the cumulative sludge into two fractions for alum solubilisation in an acid treatment facility and an alkaline treatment unit, respectively, (c) transferring the properly proportioned solubility alum from the alkaline and acid treatment units for use as a flocculation agent, and (d) screening the inert silt for final disposal [9].

METHODS

Research Design

While a raw water sample was taken from the water treatment facility at the Basra governorate (Shatt al-Arab water), household aluminium waste soft drink cans were obtained from scavengers in the Basra neighbourhood. The extraction of alum from domestic aluminium wastes was done in a lab experiment. In order to synthesise alum for this investigation, the Birni-Yauri [7–9] method was used. To test the extracted aluminium sulfate's effectiveness in preventing coagulation, environmental deterioration, and pollution, samples of untreated raw water were taken from the Shatt al-Arab. Aluminium is extracted from its ores using a significant quantity of electrical energy.

The energy necessary to make a single beverage can is roughly equivalent to that needed to operate a 100-watt bulb for 6 hours; however, this energy can be decreased by up to 95% through the recycling of spent aluminium extract [3].

The need for drinkable water has consistently put a significant financial and social burden on governmental agencies. Therefore, it is important to develop additional environmentally friendly and economically viable water treatment methods.

Study Area

The Shatt al-Arab Treatment Plant in Basra governorate is the subject of the investigation. The dam has a significant role in delivering potable drinking water for the entire Basra metropolis, including the governorate and beyond, which led to the selection of this area for the study. The Shatt al-Arab Water Treatment Plant is situated at Basrah, Khorramshahr, Abadan, Iraq. The dam was built in 2006 and put into service.

Problem Statement

Every municipal water treatment system involves the stages of coagulation and sedimentation, and alum (aluminium sulphate) plays a critical role in accelerating and realising coagulation during the water treatment process. As a result, both public and private institutions are spending a lot of money to acquire this essential ingredient, which indirectly encourages human exploitation of the earth's crust and results in sedimentation using a flocculation machine in a laboratory. Regarding the ideal requirements for standard coagulation, which include; settling time, clarity, and Total Dissolved Solid contents (TDS), as provided by the National Water Quality Standard (NWQS) and the Iraq Standard for Water Quality, conclusions were drawn regarding the effectiveness of the coagulant obtained from the extracted aluminium waste (NSDWQ). Statistical analysis was conducted using SPSS 25 for analysing the characteristics which are presented in continuous variable measurement. ANOVA employed effective analysis, and the level of significance was considered to be $\alpha=0.05$.

RESULTS AND DISCUSSION

Table 1 demonstrated that the volume of water is equal (350 ml) in both the samples before coagulation but was slightly high in the standard article (320 ml) after coagulation. The water turbidity is the same in both groups before coagulation and greatest in standard after (82 NTU) coagulation. The solids are highly dissolved in the standard group (258 ppm) after coagulation than prepared (170 ppm). The appearance of water before coagulation is muddy/ brown and clear/colorless and a little muddy/ unclear in the preparation and standard groups, respectively. The pH is decreased after coagulation in both.

Table 1. The test of coagulation action of the synthesized alum sample

Parameters	Prepared material	Standard article	P-value
Volume of water before coagulation	350 ml	350 ml	N/a
After coagulation	300 ml	320 ml	0.985
Turbidity of raw water before coagulation (NTU)	380 NTU	380 NTU	0.998
After coagulation	8 NTU	82 NTU	0.956
Total dissolve solid (TDS) before coagulation	340 ppm	340 ppm	0.978
After coagulation	170 ppm	258 ppm	0.969
Setting time	4 min	8 min	0.922
Water appearance before coagulation	Muddy/brown	Muddy/brown	
After coagulation	clear/ colourless	Little muddy/ unclear	
pH of the water before coagulation	7.4	7.4	0.998
After coagulation	3.3	6.5	0.658

The prepared material shows high conductivity (20) than the standard (15.59). The prepared material is highly acidic (1.2 pH), with high calcium (160 mg/l), sulfate (2720 mg/l), potassium (525.6 mg/l), sodium (132.66 mg/l) and low chloride (2130 mg/l), and magnesium (92.34 mg/l) compared to standard material (Table 2).

Table 2. Comparison of characteristics between prepared materials and standard articles.

Parameters	Symbol	Units	Prepared material	Standard article	P-value
Conductivity	EC	Ms/cm	20	15.59	0.558
Acidity	pH	lu	1.2	2.26	0.621
Calcium	Ca	Mg/l	160	100	0.661
Magnesium	Mg	Mg/l	92.34	97.2	0.754
Sulfate	SO4	Mg/l	2720	348.8	0.498
Chloride	Cl	Mg/l	2130	2840	0.754
Potassium	K	Mg/l	525.6	35.04	0.551
Sodium	Na	Mg/l	132.66	60.3	0.512

Wastes are produced as a result of numerous industrial production-related activities as well as other anthropogenic activities [28]. Wastes can be classified as either solid, liquid, or gaseous. Aluminium can trash the primary environmental hazard in the beverage industry. The only option to minimise or completely eliminate the environmental impact of waste is to create and put into practice an efficient waste management strategy [29–32].

The technique of recycling aluminium allows for the reuse of aluminium scrap after it has been produced to create new aluminium metal products or aluminium compounds like alum. By simply remelting the metal or by employing a chemical recovery method, fresh aluminium can be produced at a much lower cost and energy cost than by electrolysing aluminium oxide (Al_2O_3), which first needs to be extracted from bauxite ore and then processed using the Bayer process [33–36]. A unique group of substances are referred to as "alum," best exemplified by potash alum (K_2SO_4. $Al_2(SO_4)_3.24H_2O$), the only substance to which the term "alum" was legally applied. $(SO_4)_3M_2.SO_4R_2.24H_2O$ is the general formula, where 'M' and 'R' are trivalent and univalent cations, respectively [37–40]

The recycling of aluminium has significant positive environmental effects. When compared to the production of raw aluminium, recycling produces only around 5.3% of the CO_2; this figure drops even lower when the mining and transportation of the aluminium are included [41]. Additionally, open-cut mining, which devastates huge portions of the world's natural land, is most frequently utilised to get aluminium ore despite the fact that much-spent aluminium may be recycled and turned back into aluminium [42].

An illustration of an oxidation-reduction or redox reaction is the dissolving of Al(s) in aqueous KOH. The hydrogen in KOH or water is lowered from an oxidation state of +1 to zero in hydrogen gas, and the Al metal is oxidised to aluminium with an oxidation state of +3. The complex ion $Al(OH)_4^-$ is known as "aluminate." The H + ions from the sulfuric acid neutralise the base $Al(OH)_4^-$ in the interaction between the aluminate ion and sulfuric acid, which is an acid-base reaction. When more acid was applied, the dense, white gelatin precipitate of aluminium hydroxide, $Al(OH)_3$, was dissolved. Al^{3+}, K^+, and SO_4^{2-} ions are present in the solution at this moment, derived from potassium hydroxide [43].

Recycling aluminium waste containers is quite doable and could benefit individuals, towns, organisations, businesses, and entire industries in terms of the environment, economy, and community. Currently, aluminium cans are recycled to manufacture more aluminium products, such as alum, using 95% less energy than it takes to refine and smelt bauxite ore. Alum is a substance that has a wide range of uses, including water purification, deodorant, baking powder, gelatin hardening, hardening plaster casts, and as a medical astringent [44,45].

CONCLUSION

In this study, alum is prepared from aluminium waste cans. These are dissolved in potassium hydroxide to further produce illuminate and then undergo treatment with sulphuric acid, heated and then cooled as aluminium is a crucial element due to its excellent properties like low density and corrosion resistance hence used in the manufacturing of aeroplanes and is also a good conductor of electricity. The aluminium is converted into alum by recycling it through heating which produces alum that is essential in the purification of water. The study was conducted to compare the efficiency of alum that is prepared, and that is available in markets. According to the study, water volume was roughly identical in both samples prior to coagulation but somewhat higher in the standard article following coagulation. Before coagulation, the water turbidity is the same in both groups, and after coagulation, the standard has the highest turbidity. After coagulation and preparation, the solids in the standard group are substantially dissolved. In the prepared and standard groups, the pre-coagulation appearance of the water is muddy/brown, clear/colourless, and just a little muddy/ unclear. After coagulation, the pH is lowered in both. The produced substance exhibits higher conductivity than usual. When compared to the standard material, the manufactured material is significantly more acidic and contains higher levels of calcium, sulphate, potassium, and sodium. The study concludes that there are no relevant differences in using the alum that is available in markets for the same purpose and that is prepared.

Recommendations

The author further recommends carrying out more studies regarding the usage of alum that is prepared in the laboratory. The alum prepared in this method from waste cans can be environmentally friendly and economical, which would reduce the cost burden to the state and the citizens. Therefore, more similar studies should be conducted throughout the state, and more advanced studies should be conducted to get the approval of the methodology from the governorate; hence, the process of water treatment by using prepared alum can be brought into practice.

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