Environmental Research Journal
MEDWELL PUBLICATIONS SINCE 2000

Assessing the Effectiveness of Synthetic Alum from Household Aluminum Waste in Water Treatment

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Keywords: Alum, water treatment, potassium hydroxide, coagulant, environment friendly, economically viable

Abstract: The study assessed the effectiveness of synthetic alum from household Aluminum waste in water treatment. The objective was to determine the possibility of the reuse of household aluminum extract as a coagulant in water treatment as well as assessing the efficiency of extract from the aluminum waste in coagulation process of water treatment. Alum potash was synthesized from household Aluminum wastes. The synthesized alum was analyzed there after for the quantity and type of ions present, coagulation efficacy, acidity/alkalinity as well as the economic feasibility. The results of the research revealed the effectiveness of the use of aluminum sulfate extracted from domestic waste as a panacea to the rising cost of water treatment. Also, the research developed an alternative to conventional alum used in water treatment through an environment friendly mechanism of waste to wealth. The results of the study also indicated that aluminum sulfate derived from domestic household waste tends to have higher turbidity reduction than the conventional alum. Conventional aluminum sulfate is costlier than alternative coagulant derived from domestic waste. Hence the cost effectiveness of substituting conventional alum with the coagulant extracted from aluminum domestic waste was established. In conclusion, substituting conventional alum with aluminum sulfate derived from domestic waste has both functional and economic efficiency. The study recommends that policy should be developed to support production and use of environment friendly coagulant through the production of aluminum sulfate extracted from household domestic wastes.

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Page No.: 11-15
Volume: 15, Issue 2, 2021
ISSN: 1994-5396
Environmental Research Journal

INTRODUCTION

Water is a natural resource without which all living things cannot exist[1]. It is a basic requirement for all living things to have access to water if they have to be alive. Water is important for domestic, industrial, commercial and agricultural purposes. Although about 70% of our planet earth is covered by water, 97% is basically saltwater while 3% is freshwater. Only 1% of the global freshwater is available for human consumption as 70% of that fresh water is frozen in icecaps of Antarctica and Greenland; most remaining is present as soil moisture, or lies in deep underground aquifers as groundwater not easily accessible to human use[2]. The available water for consumption has been threatened by pollution as a result of various human and natural activities. There is the need for proper treatment of water before consumption by humans. Various water treatment plants in sub-Sahara Africa make use of Alum as coagulant in their water treatment.

Aluminum is one of the most indestructible materials used in producing metal containers. The average life of an aluminum Can is about one hundred years. Although aluminum is the third most abundant element in the earth's crust, the cost of its extraction from the soil is very high and, in the process, causes severe damage to the environment. The major source of aluminum is from bayswater, the hydrated form of aluminum oxide, $Al_2O_3{\cdot}2H_2O$ [3]. Aluminum is classified into pure aluminum which includes Cans, aluminum foil papers, household aluminum products such as kitchen utensils, photo frames and some electronic appliances used in various homes.

Household aluminum waste are trash which are made of aluminum, considered unwanted and discarded into the environment which can be recycled into different materials which could be of economic importance and benefit. Aluminum can be source from a variety of household items and is a great metal to trade with local scavengers and metal collectors for recycling[4]. Household aluminum wastes that come from pure aluminum class includes used Cans, aluminum foils, food containers, broken aluminum pots and spoons, cauteries, baking trays and other cook wares[5]. Similarly, household electronics such as lamps and furniture items made from aluminum such as chairs, tables, picture frames, and decorative panel scan be easily reused or recycled for best economic benefits[6].

Instead of recycling aluminum into new metal material, a chemical process can be used to transform household aluminum extract into a useful chemical compound, potassium aluminum sulfate do dehydrate, $Kal\ (S04)_2{\bullet}12H_20$, commonly called "alum" [7]. Alum is widely used in dyeing of fabrics, in the manufacture of pickles, in canning some foods and production of kitchen utensils such as pots, spoons, cauteries and as a coagulant in water purification and waste-water treatment plants.

The class of chemical compounds known as "alums" are ionic compounds that crystallize from solutions containing sulfate anion, $SO_{42-,}$ a trivalent cation, such as $A1^{3+}$, Cr^{3+}, or Fe^{3+}, and a monovalent cation, such as $K^{+,}$ Na^+, or NH_{4+}.

Most alum crystallizes readily as octahedrons or cubes, which under the appropriate conditions may grow to considerable size[7]. Hence the extract can be obtained in large quantities presumable at lower cost that stands a good chance of becoming a reliable source of coagulant for water treatment plant.

MATERIALS AND METHODS

Household aluminum wastes were procured from scavengers in Batagarawa area of Katsina state while raw water sample was collected from Ajiwa dam water treatment plant of Katsina State.

Laboratory experiment was used for the extraction of alum from the household aluminum wastes. The method that was adopted in the synthesis of alum for this study is that of Birni-yauri[8]. The extracted aluminum sulfate was administered into samples of the untreated raw water collected from Ajiwa dam to monitor its effectiveness in coagulation and environmental degradation and pollution. The amount of electrical energy utilized in the extraction of aluminum from its ores is very high. To produce a single beverage Can, the energy needed is about the same as that required in keeping a 100-watt bulb lit for 6 hours, that energy can be reduced by up to 95% by recycling of used aluminum extract[3]. The need of potable water for consumption has continuously constituted a great financial and social budget to public authorities. Therefore, it is pertinent to devise other economically and environment sustainable alternatives for water treatment process.

Study area: The study area is the Ajiwa dam water treatment plant in Katsina state. The choice of this area for the study is based on the important role of the dam in providing potable drinking water for the entire Katsina metropolis and beyond. The Ajiwa dam water treatment plant is located in Batagarawa local Government of Katsina state North-west, Nigeria within the coordinates 12°95'N and 7°75'E.The dam was constructed in 1974, and commissioned in 1975, with an average capacity of 22,730,000 m^3 million liters of raw water (Fig. 1).

Problem statement: Coagulation and sedimentation are very vital stages in every municipal water treatment system and the role of Alum (Aluminum Sulfate) in acceleration and actualization of Coagulation in water treatment process is very significant. In view of that, government and private institutions are spending large sums of money for the procurement of this vital additive by extension stimulating the process of its exploitation from the earth's crust by man which translates into sedimentation process with the aid of a flocculation machine in the lab. Inferences were drawn in terms of the effectiveness of the coagulant obtained from the extracted aluminum waste in relation to the ideal requirement for standard coagulation which includes; settling time, clarity and Total Dissolved Solid contents (TDS) as provided by National Water Quality Standard (NWQS) and Nigeria Standard for Water Quality (NSDWQ).

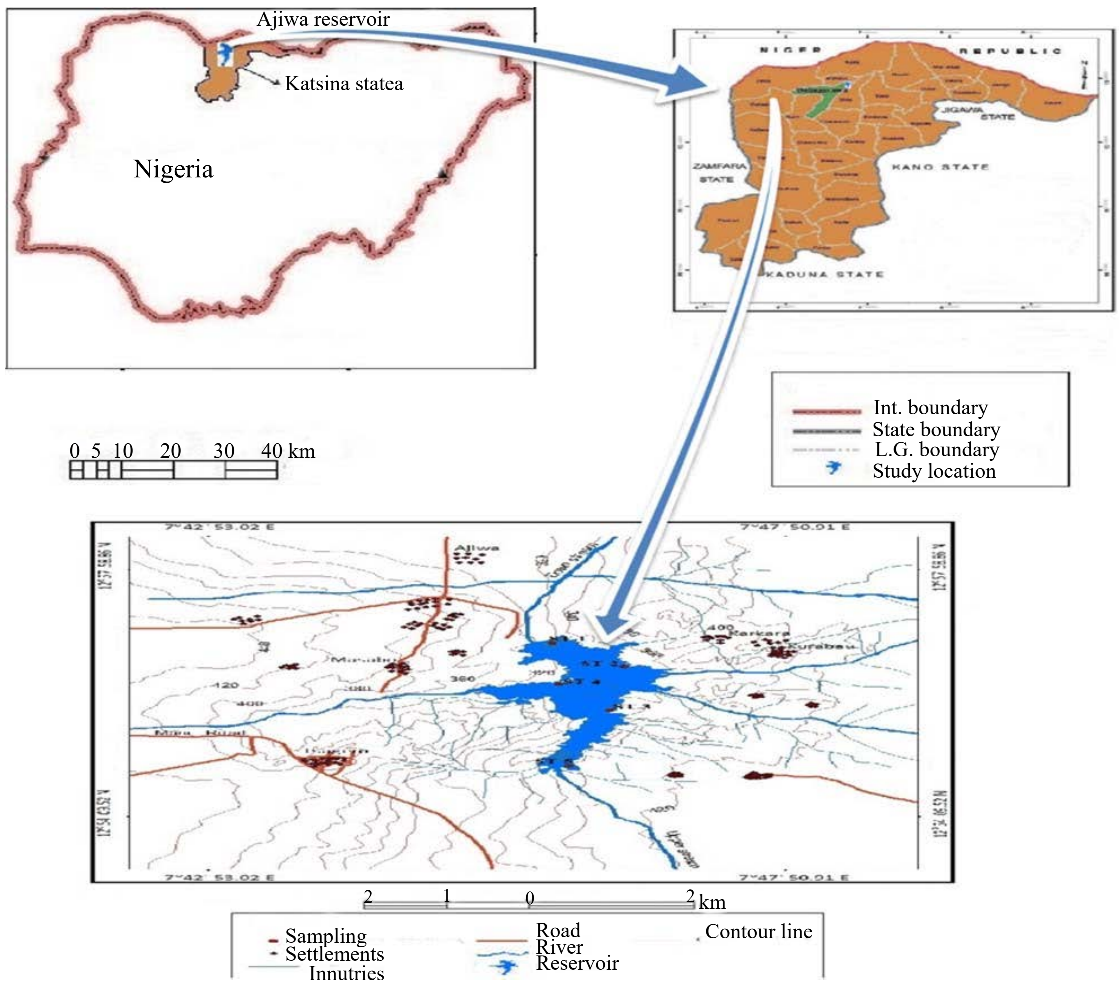

Fig. 1: Map of Nigeria showing Katsina state and Ajiwa dam reservior

RESULTS AND DISCUSSION

Table 1 presents the household aluminum materials used, classes and their respective compositions. The materials used all contain aluminum and are disposed beverage Cans, broken serving spoons and aluminum food containers. The household aluminum wastes used all belong to non-ferrous class of metal and their various compositions are Al, Si, Iron, Mg and anganese for beverage Cans while the broken serving spoons are composed of cast iron, Iron, Mn, Si. The aluminum food containers composed of about 92-99% aluminum.

Table 2 shows the qualitative analysis of ions present in the synthesized aluminum sulfate produced. The first test was carried out to confirm the presence of sulfate ion ($SO4^{-2}$). The result indicated the presence of sulfate ion in the alum sample produced.

The second test was to confirm for the presence of potassium ion (K^{+}). The result indicated the presence of potassium ion in the alum sample produced. The final test was carried out to confirm the presence of aluminum ion (Al^{3+}).The result indicated the presence of aluminum ion in the alum sample produced.

Table 3 presents the quantitative analysis on ions present in the aluminum sulfate. These were determined using a flame photometry and Atomic Absorption Spectrophotometer (AAS). Potassium ion has a quantity of 163600,00 mg kg^{-1}, flame color of violet with an emission wave length of 766 nm, Sulfate ion is 51176,84 mg kg^{-1} with a wavelength of 420 nm (nanometer) while Aluminum ion is 4155,00 mg kg^{-1} with a wavelength of 310 nm.

Table 4 presents the results of Coagulative strength/action of the synthesized aluminum sulfate. Three beakers of 500 mL containing 300 mL of raw water were used to determine the coagulative strength of the sulfate sample produced from household aluminum waste and comparing it with conventional alum in the lab to

Table 1: Household aluminum Materials, class and their respective compositions

Material	Class of metal	Composition
Beverage aluminum cans from household wastes	Non-ferrous metal	Al, Si, Iron, Mg, Manganese
Serving spoon made up of aluminum disposed as waste	Non-ferrous metal	Aluminum from beverage cans and cast iron (iron, Mn, Si)
Aluminum food container used at home and disposed	Non-ferrous metal	92-99% aluminum

Field survey 2021

Table 2: Qualitative analysis of ions present in the synthesized alum crystal

Test	Observations	Inferences
Alum solution+Aqueous $Bacl_2$ Solution	White precipitate was formed and insoluble (after 24 h)	SO_4^{-2} was confirmed
Solid alum crystal+heat (20 sec)	Red flame turned to pale purple flame color	K^+ was confirmed
Solution+KOH+H_2SO_4 (aq) in drop and excess	Thick, White gelatinous precipitate formed insoluble in drop but soluble in excess	Al^{3+} was confirmed

Table 3: Determination of quantity of ions in the alum sample

Ions	Quantity (mg kg^{-1})	Detection limit (mg kg^{-1})	Flame color	Emission wavelength (nm)	Methods
Potassium ion (K^+)	163600,00	0.2	Violent	766	Flame photometer
Sulfate ion (SO_4^{-2})	51176,84	NA	NA	420	Spectrophotometer
Aluminumion (Al^{3+})	4155,00	0.3	NA	310	Spectrophotometer

Table 4: Results for test of coagulation action of the synthesized Alum sample

Parameters	Beaker A mass = 1 g (synthesized alum sample)	Beaker B control	Beaker C mass = 1 g (alum from lab)
Volume of raw water (mL) before coagulation	300 mL	300 mL	300 mL
After coagulation	250 mL	280 mL	250 mL
Turbidity of raw water before coagulation (NTU)	379 NTU	379 NTU	397 NTU
After coagulation (NTU)	6 NTU	80 NTU	8 NTU
Total dissolve solid (TDS) before Coagulation	338 ppm	338 ppm	338 ppm
After coagulation	169 ppm	256 ppm	186 ppm
Settling time	3 min	7 min	3 min
Water appearance before	Muddy/Brown	Muddy/Brown	Muddy/Brown
Water appearance after coagulation	Clear and colorless	Little muddy/unclear	Clear and colorless
pH of water before coagulation.	7.3	7.3	7.3
pH of raw water after coagulation.	3.2	6.4	3.6

Laboratory analysis (2021)

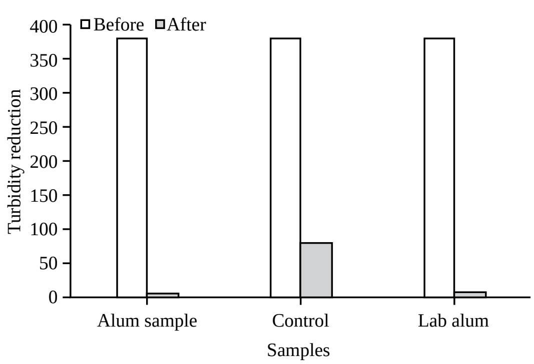

Fig. 2: Turbidity reduction

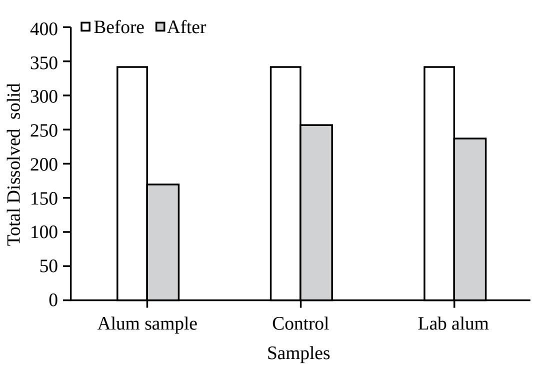

Fig. 3: Total dissolved solid

determine its effectiveness. One gram of the alum sample produced and 1 g of conventional alum were dissolved in the 300 mL of the raw water in beakers A and C respectively while beaker B served as the control sulfate sample produced from household aluminum waste and comparing it with conventional alum in the lab to determine its effectiveness. One gram of the alum sample produced and 1 g of conventional alum were dissolved in the 300 mL of the raw water in beakers A and C respectively while beaker B served as the control. The beakers were placed on a flocculator at 100 rpm for 30 min so as to monitor some parameters such as Turbidity reduction which was 379 NTU in all the beakers before coagulation (Fig. 2). At the end of the coagulation, beaker A of alum sample result showed 3 NTU, 80 NTU for beaker B (control) and 6 NTU for conventional Alum in beaker C. The result for TDS (Total dissolve solid) before the coagulation was 338 ppm for all the water samples and after the coagulation the results showed 169 ppm for beaker A and 18 ppm for beaker C while beaker B showed 256 ppm (Fig. 3).

The pH value of the water samples before coagulation was 7.3, whereas, after coagulation it become 3.2 for beaker A, 3.6 for beaker C, and 6.4 for beaker B respectively (Fig. 4). For settling time, Beakers A and C containing the aluminum sulfate of both synthesized and conventional alum settled at the first three minutes while beaker B which is the control settled at 7 min.

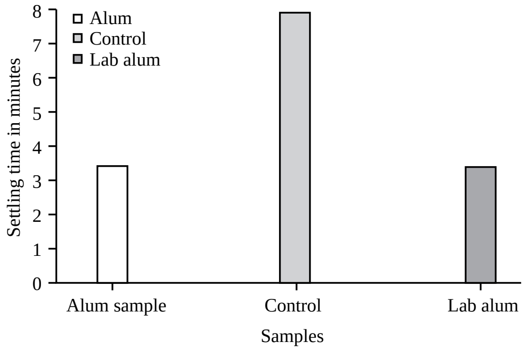

Fig. 4: Settling time activity

CONCLUSION

The research results have shown that aluminum sulfate derived from domestic waste can serve as a good substitute to conventional alum for water treatment. Aluminum sulfate derived from domestic waste proved to have same settling time with the conventional alum but faster than conventional alum in formation of floccs. Aluminum sulfate derived from domestic waste tends to have higher turbidity reduction than the conventional alum. It is therefore be concluded that substituting conventional alum with aluminum sulfate derived from domestic waste has both functional and economic efficiency in water treatment in Nigeria.

RECOMMENDATIONS

Government should encourage aluminum product reuse in water industry through formal evaluation of various concentrations of aluminum in domestic waste. Policy should be developed to support production and use of environment friendly coagulant. Production of aluminum sulfate extracted from household domestic waste should be encouraged to minimize loss of energy common to the process of production of conventional aluminum sulfate.

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