



Removal of Aluminum (III) from Water by Adsorption on the Surface of Natural Compound

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Received: 30/03/2023

Accepted: 21/05/2023

Published: 20/06/2023

Abstract

Although aluminum ions are not toxic, drinking water containing a high amount of aluminum can cause some illnesses such as cardiac arrest, glucose intolerance anemia, and osteomalacia (soft or brittle bones) in humans. Many methods have been introduced to remove aluminum from water but adsorption is the most simple and effective way to remove aluminum from water. This study aims to study the performance of removing aluminum (III) from water using Guava leaves. In this study, some effective parameters on aluminum removal from the contaminated water such as pH, temperature, contact time, and the effect of speed of rotation on the removal of metals absorbance dosage, were investigated. There is a remarkable aluminum (III) removal efficiency for Guava leaves in the range of aluminum concentration of 50 to 250 ppm. The contact time of 120 minutes is the suitable contact time for adsorption. The optimum pH for the aluminum adsorption from the water was a acidic (pH of 6). It is obvious that the 0.5 mg dose is the most efficient adsorbent dose, and the ideal temperature is 25-30° C.

Keywords: Adsorption, Aluminum, Guava leaves, pH

1 Introduction

The world has become more concerned about water issues. Besides, water pollution can affect the international relations of nations that have one or more shared water resources. Although about 71% of the Earth's surface is covered by water, only 2.5% of it is fresh water. According to the WHO, water scarcity is affecting around three out of every four people globally, and the issue is expected to get worse as the demand for water increases. People rely on dirty water, which can cause various diseases. Humans are mainly responsible for the management of the world's natural resources. To meet the increasing water demand, new methods should be developed to improve the quality of the water supply [1,2]. Water pollution Came from any change in its chemical or physical properties and makes it inappropriate for various uses. [3] There are different causes of water pollution like-Sewage and wastewater 2-Mining activities 3-Global warming [4] 4-Industrial waste. The sources of water pollution are different from oneplace to another. The inorganic contamination of water is different from organic one because it cannot be metabolized, therefore removal of inorganic contaminates depends on the formation of bonds between them and a solid surface [5]. There are many techniques used for removing inorganic contaminates the removal process must be simple, effective, and inexpensive. [6] An example of removal methods is (Chemical precipitation, Ion exchange, Cementation, coagulation and flocculation, Membrane filtration, Ultrafiltration, Reverse osmosis, and Adsorption. [7] The adsorption method offers flexibility in design and operation. Also, adsorption is economically effective for dilute solutions and sometimes it is a reversible process [8].

Aluminum makes up about 8% of the Earth's crust [9], it is the third most abundant element after oxygen and silicon.

Because Most of the aluminum derivatives exhibit low toxicity, its compounds enjoy wide and large-scale applications. The amount of aluminum in seawater varies between 0.013 and 5 ppm while river water generally contains about 400 ppm. Regular aluminum concentrations in groundwater are about 0.4 ppm because it is present in soils as water-insoluble hydroxide. At pH 4.5 solubility rapidly increases, causing aluminum concentrations to rise above 5 ppm, this may also occur at very high pH values. Dissolved Al^{3+} ions are toxic to plants. Also, Aluminum is mainly toxic to fish at pH values of 5-5.5. The total aluminum concentration in the human body is approximately 9 ppm (dry mass) and in some organs, specifically the spleen, kidneys, and lungs, concentrations up to 100 ppm may be present. Large aluminum intake may negatively influence health. This is related to nerve damage and kidney damage, and probably aluminum is mutagenic and carcinogenic. [10] Aluminum intake mainly occurs through food and drinking water. Removal of metal ions from industrial effluents is a major challenge of wastewater treatment. Heavy metals occur as contaminants of liquid waste discharged from various industries such as textiles, radiator manufacturing, electroplating, smelting, etc. This research aims to study the removal of Al^{3+} which is a hazardous element in the environment at a high concentration by adsorption using Guava leaves as a natural, low-cost adsorbent. The parameters affecting the adsorption process as Al^{3+} initial concentration, adsorbent doses, pH, temperature, and rate of stirring.

2 Materials and methods

2.1 Chemicals

All chemicals used were of analytical grade. A stock solution of aluminum concentration 1000 mg/l was prepared by dissolving 0.056 g of aluminum potassium sulfate [Al K

(SO₄)₂.12 H₂O] in 1000 ml of distilled water. Diluting Al³⁺ stock solution from 1000 mg/l to 50,100,150 200, and 250 mg/l was carried out by using distilled water under dilution law. The pH of solutions was adjusted to the required value by the addition of 0.1 M NaOH or 0.1 M HCl at a fixed temperature of 298 K.

2.2 Preparation of adsorbent

Guava Leaves (cleaned) were washed well with water, then washed with diluted acid, dried primarily by the sun, then dried in the oven at a temperature of 323 K, grinding by an ordinary food processor (model bl 333), then sieved through the sieve pore size of 0.4 – 0.3 mm the powder was then available to use in each experiment.

2.3 Apparatus and Materials

A definite volume of metal ion stock solution with known initial concentration was stirred with a definite amount of aluminum metal for a stipulated time in a digital magnetic stirrer MS-H-Pro with temperature sensor PT 1000 using a Teflon magnetic stir bar of 2 cm length. Sample (0.5 ml) diluted to 5 ml by distilled water and used atomic absorption spectrophotometer model Perkin Elmer (Pin AAcle 900 T) was used to analyze concentrations of the dissolved Aluminum Crison GLP21 pH-meter was used to adjust pH of the solution.

2.4 Procedure

The patch techniques are used due to the large size of Guava leaves. Therefore, it has not affected the continuous sample taken with time intervals. These experiments were performed by stirring Guava leaves and 200 ml of hydrated aluminum potassium sulfate [Al K (SO₄)₂.12 H₂O]. Different pH values of the solution ranging from 2-7 were studied. Experiments were carried out at different temperatures 298,303,308, and 313 K, stirring speeds of 100, 200, 300, 400, and 500 rpm, initial Aluminum (III) ion concentrations were 50, 100, 150, 200, and 250 mg/l, and Guava leaves dosage

0.1,0.2,0.3,0.5, and 0.7 the samples analyzed by using atomic absorption spectrophotometer. The Data were analyzed by using the equilibrium of the adsorption and kinetics study.

3 Results and Discussion

The efficiency of the adsorption process was calculated from the change in % removal value with time, which can be calculated from the equation.

$$\% \text{Removal} = \frac{C_o - C_e}{C_o} \quad (1)$$

Also, the amount of metal absorbed was calculated from the equation.

$$q_t = \frac{(C_o - C_t)V}{m} \quad (2)$$

The ratio between the quantity absorbed and that remaining in solution at a fixed temperature at equilibrium was calculated from the equation.

$$q_e = \frac{(C_o - C_e)V}{m} \quad (3)$$

where C_o (mg/l) is the initial metal ion concentration in solution, C_e (mg/l) is the equilibrium concentration of metal ions in solution, C_t(mg/l) is the concentration of the metal ion in solution after the time (t), (m) is the mass of Guava leaves in (g) and (V) is the volume of the solution.

3.1 FT-IR studies

From Fig (1,2) we notice that band 3423 Cm⁻¹ was shifted to 3452 Cm⁻¹, which is for stretching (OH) [11] group in Guava leaves because of the adsorption of aluminum in the Guava leaves surface

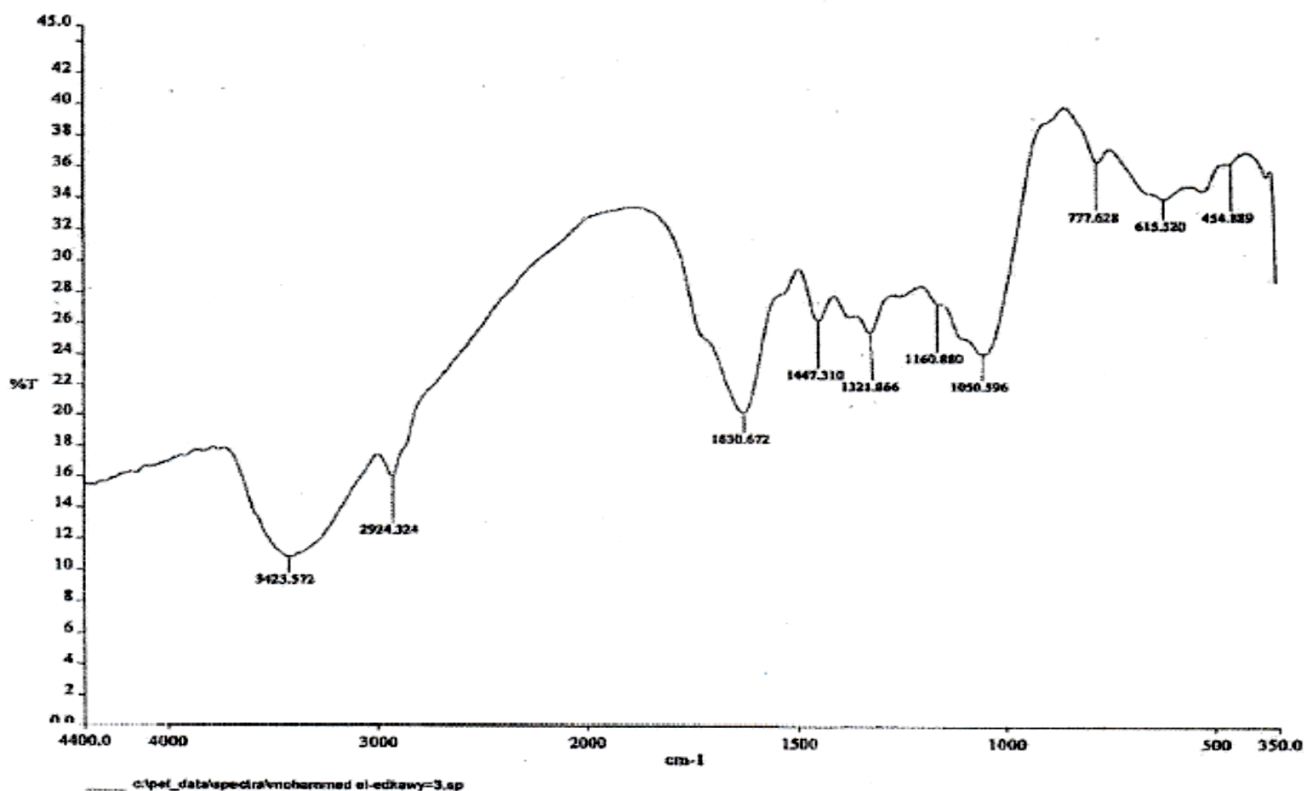


Figure 1: IR spectrum for Guava leaves

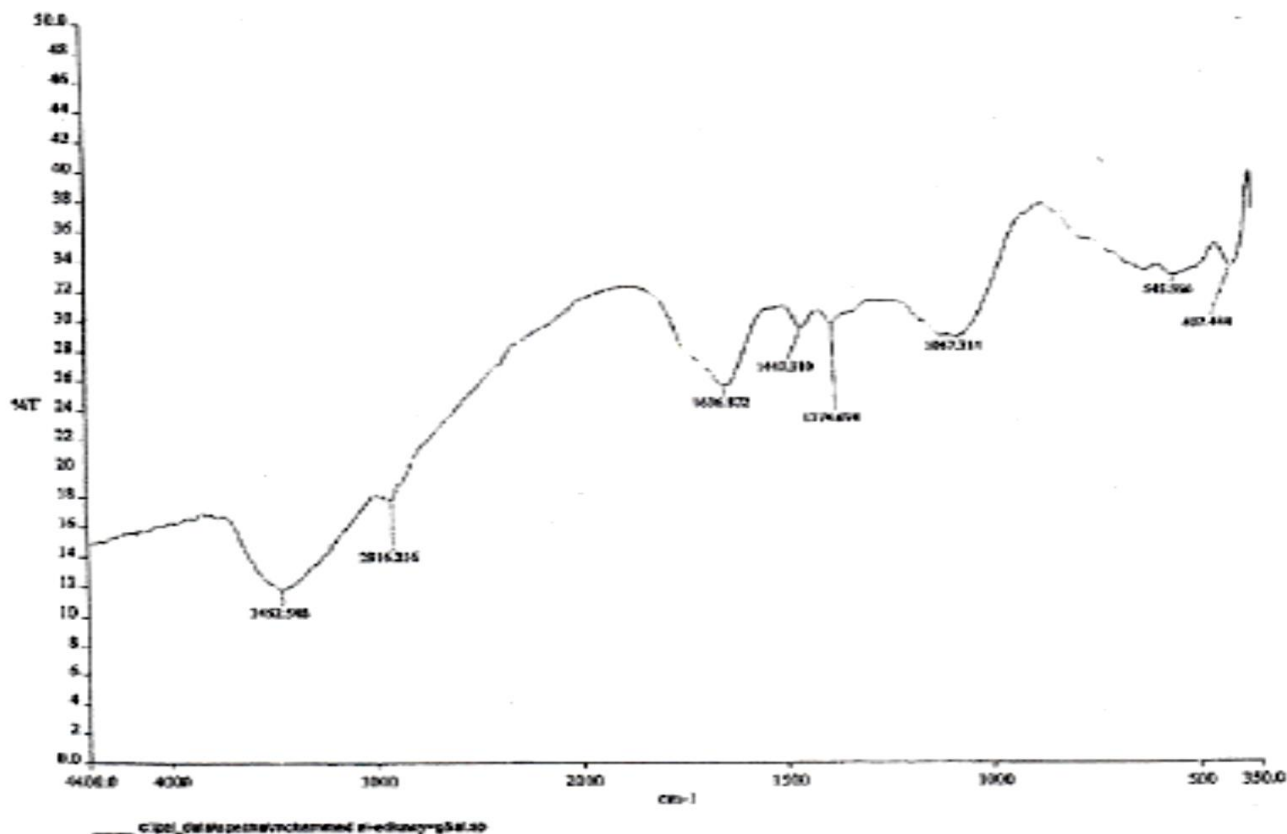
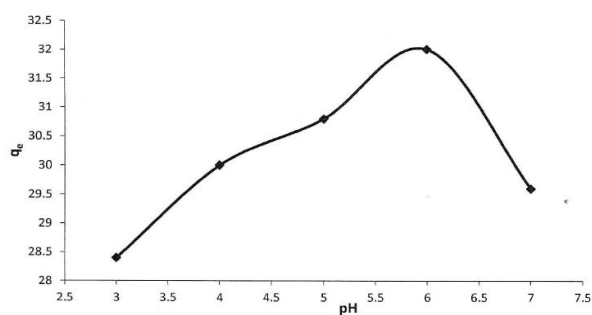
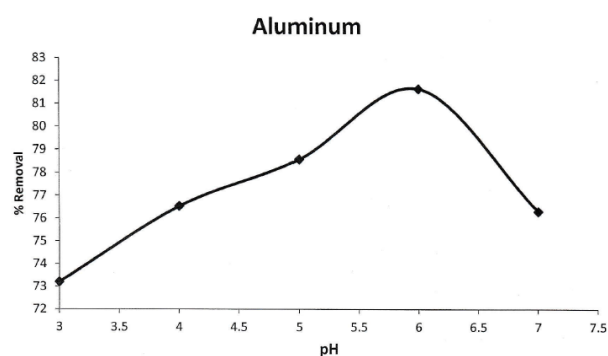
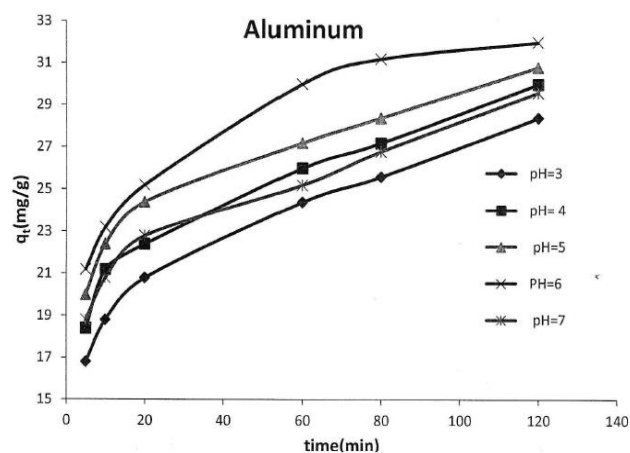
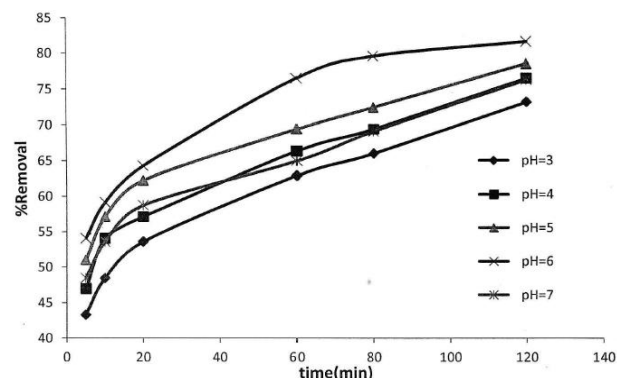


Figure 2: IR spectrum for Guava leaves absorbed Aluminum

3.2 Effect of pH

Figures (3, 4) show the effect of pH on q_c and % removal also Figures (5, 6) show the change of q_t and %removal with time (120) min at different pH. The graph shows that the adsorption of Al^{3+} on Guava leaves surface increases in acidic solution at optimum pH=6 [12].

Figure 3: Effect of pH on adsorption of Al^{3+} Figure 4: Effect of pH against % removal of Al^{3+} Figure 5: Effect of q_t (mg/g) on adsorption of Al^{3+} at different pHFigure 6: Effect of % removal of Al^{3+} at different pH

3.3 Effect of contact time

Figures (7, 8) show that percentage of removal records significant upward values with time and reaches a maximum at 120 min this indicate that the concentration of Aluminum in the solution decreases rapidly within the first 30 min and the removal was completed at 120 min. The removal of metal ions can be derived into two stages: one in which the removal rate is very high. It is very important to determine the equilibrium time which is the contact time characterized by unchanging Al^{3+} concentration in the solution achieved after 30 min for all concentrations of solutions; this period is denoted as the second stage of the adsorption. [13] Depending on the concept of adsorption sites we can explain that the vacancy on it at first stage Al^{3+} could easily interact with these sites. The adsorption capacity was almost constant for all concentrations and as such it was considered as the equilibrium time of Al^{3+} onto guava leaves.

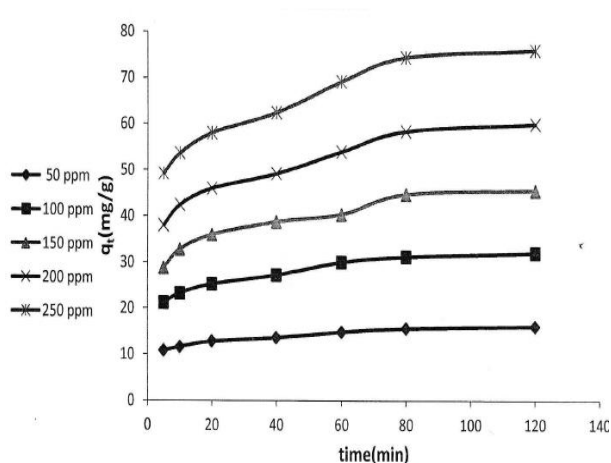


Figure 7: Effect of q_t (mg/g) on adsorption of Al^{3+} at different initial concentrations

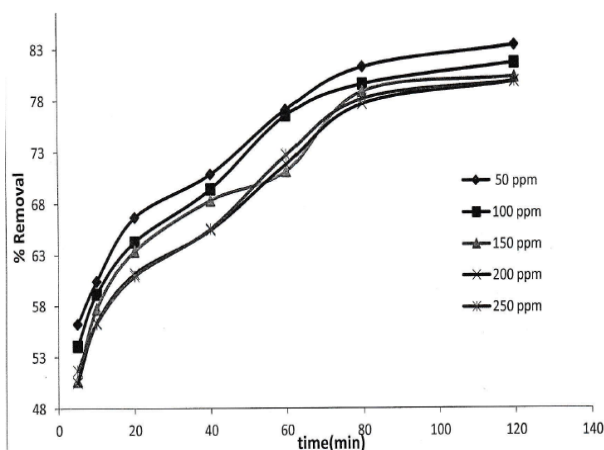


Figure 8: Effect of % removal and contact time on the adsorption of different Al^{3+} at different initial concentrations

3.4 Effect of adsorbent dose

Figures (9, 10) shows that the removal percentage of Al^{3+} ions increases as the amount of adsorbent increase. Adsorption increased from 74.48 to 84.15% with an increase in the adsorbent dose from 0.3 to 0.7 g/200 ml. The number of adsorptive sites or surface area increases with increasing the weight of the adsorbent which obtains many available exchangeable sites which enhance the percentage of metal removal. However, the sorption capacity (q_t) decreases with the adsorbent dose because at the higher dose, the solution ions

concentration drops to a lower value and the system reaches equilibrium at lower values of (q_t) indicating the adsorption sites remain unsaturated (it may be due to the overlapping of active sites at higher doses causing a decrease in the effective surface area resulting in the conglomeration of exchanger particles [14-15]).

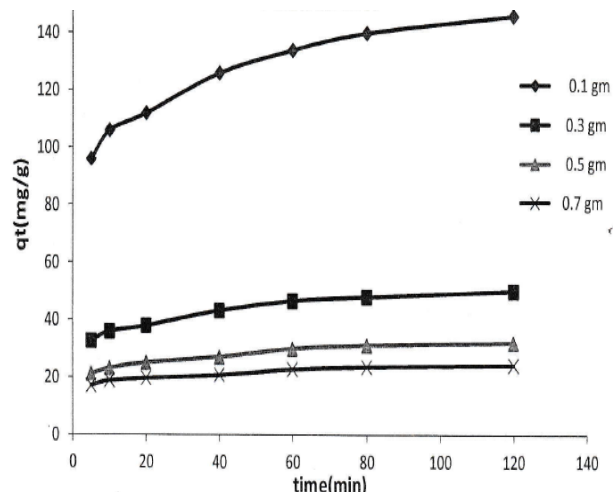


Figure 9: Effect of time on q_t (mg/g) on adsorption of Al^{3+} at adsorption of different doses of guava leaves

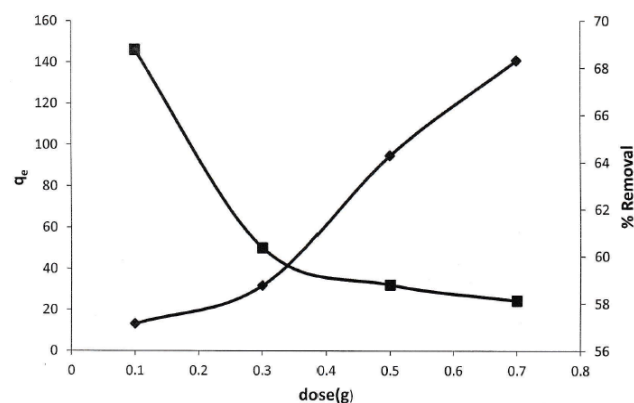


Figure 9: Effect of time on q_t (mg/g) on adsorption of Al^{3+} at adsorption of different doses of guava leaves

3.5 Effect of speed of rotation on the removal of metals

Figure (11) shows that the speed of rotation enhances metal removal from aqueous solutions. This is because metal ions meet resistance at the liquid phase, through their transportation to the solid phase, through the boundary layer. Therefore, the rotation led to a decrease in the boundary layer and a decrease in the resistance to the transportation of metal ions. The removal of Al^{3+} reaches 86.59% at 500 rpm.

3.6 Effect of temperature

On monitoring the temperature effect adsorption experiments were conducted at 298, 303, 308 and 313 K. The effect of temperatures on the adsorption capacity of Guava leaves was studied at constant initial concentration of 100 mg/l and 300 rpm of Al^{3+} , optimum pH value of 6 and 0.5 g/200 ml of Guava leaves. Fig. (12, 13) show the increasing of removal efficiency by increasing the temperatures and also the adsorption capacity increase with time to 120 min at different temperatures. An increase in temperature involves increasing the mobility of Al^{3+} and decreasing the retarding forces acting on diffusing ions; these results in the enhancement in the sportive capacity of the adsorbent, increasing the chemical

interaction between adsorbate-adsorbent and creation of active surface centers or by an enhanced rate of intra-particle diffusion of Al^{3+} ions into the pores of the adsorbent at higher. There are many publications about complexation behavior and its behavior [16-25].

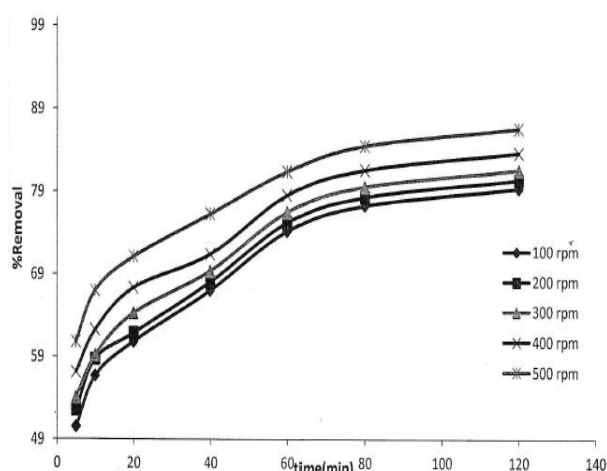


Figure 11: Effect of contact time on the adsorption of Al^{3+} at different rpm

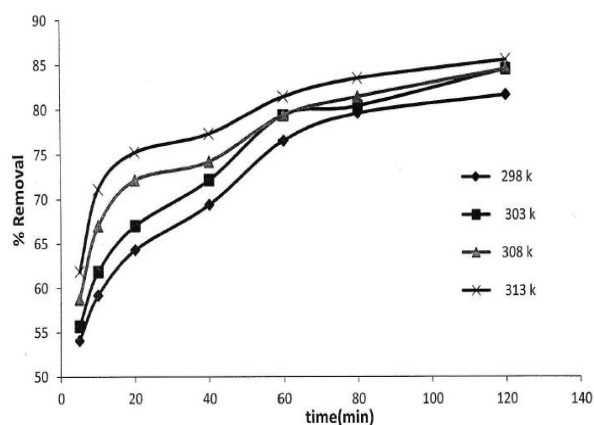


Figure 12: Effect of time on % removal of Al^{3+} and different temperatures

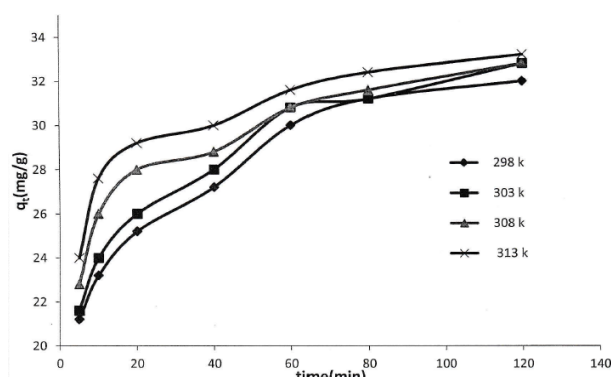


Figure 13: Effect of time on q_t (mg/g) of Al^{3+} adsorption and different temperatures

4 Conclusion

During this work, the investigation of the adsorption of metal ions by Guava leaves as a natural adsorbent show the following results

1- The Guava leaves record an effective percentage removal for the Al^{3+} metal using a 0.5 gm sample size Guava leaves

could remove about 90% of Aluminum with the initial concentration of 100 ppm within 120 min.

- 2- Significant increase in the removal of Al^{3+} with the increase in the Guava leaves and increase in temperature of the experiment.
- 3- Time 120 min is the suitable contact time for adsorption. However, the removal rate did not remain the same at other contact time
- 4- The optimum pH for the percentage adsorption of metal ions is found to be acidic pH=6.
- 5- From the data obtained from different adsorbent doses. It is obvious that 0.7 gm dose is the most efficient adsorbent dose and the best temperature is 313K.

Ethical issue

Authors are aware of and comply with, best practices in publication ethics specifically about authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. Authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that no conflict of interest would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution to data collection, data analyses, and manuscript writing.

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