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Removal of Cadmium (II) from Water by Adsorption on Natural Compound

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Abstract

The removal of a high level of cadmium in drinking water by Guava leaves as a natural material is a simple way to produce high-quality water. The study revealed that Guava leaves were able to effectively remove a significant percentage of cadmium. Using a 0.5 gm sample size of ground Guava leaves could remove 90% of cadmium with an initial concentration of 100 ppm within 120 min. A significant increase in the removal of Cd (II) with an increase in the Guava dosage and increase in temperature could be observed. There is a remarkable efficiency for Guava leaves in the range of cadmium concentration of 50 to 250 ppm. Time 120 minutes is the suitable contact time of adsorption that achieves the highest cadmium removal from water. The optimum pH for having the highest amount of cadmium removal was around 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, Cadmium, Guava leaves, pH

1 Introduction

Water is one of the most important substances on earth. All plants and animals must have water to survive. If there is no water, there would be no life on earth. The world is entering the third millennium; the water issue has become one of the most important issues which take the concern of the whole world. Besides, water pollution affects the international relations between countries that share water resources and may cause wars. Water covers about 71% of the earth's surface, but only 2.5% of the earth's water is freshwater (1). World Health Organization WHO has reported that water scarcity is affecting a third of people in the world and the problem is continuously increasing because of the rising water demand (2). Therefore, people depend on polluted water which causes many diseases. The dependence of humans is mainly on their ability to manage the natural resources; therefore, new methods should be provided to purify water and increase its quality to encounter overpopulation. Water pollution came from any change in its chemical or physical properties and make it inappropriate for various usage (3). There are different causes of water pollution like1-Sewage and wastewater 2-Mining activities 3-Global warming 4-Industrial waste (4). The sources of water pollution are different from one place to another (surface water pollution, Groundwater pollution, Nutrients pollution, microbiological pollution, Chemical water pollution and, pollution by metals). The inorganic contamination of water is different from organic one because they cannot be metabolized, therefore removal of inorganic contaminates depends on the formation of bonds between them and a solid surface (5). There many techniques used for removing of inorganic contaminates the removal process must be simple, effective, and inexpensive (6). An example for the removal methods are (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 a dilute solution, and sometimes it is a reversible process (8).

Cadmium compounds have varying degrees of solubility ranging from very soluble to nearly insoluble (9). the solubility affects their absorption and toxicity. The average concentration of cadmium in the earth's crust is between 0.1 and 0.5 (ppm) It was discovered in 1817 simultaneously by Stormier and Hermann as an impurity in zinc carbonate. Cadmium is listed in the European Restriction of Hazardous Substances (10). because of its toxicity and nickel-cadmium batteries have been replaced with nickel-metal hydride and lithium-ion batteries. Cadmium is an extremely toxic industrial and environmental pollutant classified as a human carcinogen (Group 1) - according to International Agency for Research on cancer. According to Environmental Protection Agency (EPA); and 1B carcinogen classified by European Chemical Agency (ECHA). Cadmium and its salts are severe lung and gastrointestinal irritants that can be fatal by inhalation and ingestion. Acute ingestion of as little as 10 mg of cadmium chloride can cause pulmonary toxicity, such as pulmonary edema, emphysema, and bronchitis (11).

This research aims to study the removal of Cd^{2+} 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

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Cd^{2+} 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 Cadmium Cd^{2+} of concentration 1000 mg/l was prepared by dissolving 0.558g of Cd Cl_2. H_2O in 1000 ml of distilled water. Dilute Cd^{2+} 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 0.1M NaOH or 0.1 M HCl at a fixed temperature of 298K.

2.2 Preparation of adsorbent

Guava Leaves (cleaned) washed good by water, then washed with dilute acid, drying primarily by the sun, then drying by oven at a temperature of 323K, grinding by ordinary food processor **(**model bl 333**),** then sieved through the sieve pore size of 0.4 – 0.3mm 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 Cadmium metal for a stipulated time in digital magnetic stirrer MS-H-Pro with temperature sensor PT 1000 using 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 900T) was used to analyze concentrations of the dissolved Cadmium Crison GLP21 pH-meter was used to adjust pH of the solution.

2.4 Procedure

The patch techniques were 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 250 ml of Cadmium chloride solution Cd Cl_2. H_2O. Different pH values of the solution ranged from 2-7 were studied. Experiments were carried out at different temperature 298,303,308, and 313 K, stirring speed 100, 200, 300, 400 and 500 rpm, initial cadmium (II) ion concentration were 50,100,150,200 and 250mg/l and Guava leaves dosage 0.1,0.2,0.3,0.5, and 0.7 the samples analyzed by using atomic absorption spectrophotometer.

3 Results and discussion

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

$$\% \, Removal = \frac{C_o - C_e}{C_o} \times 100 \quad (1)$$

Also, the amount of metal absorbed can be 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 is the initial cadmium ion concentration in solution in mg/l, Ce is the equilibrium concentration of cadmium ion in solution in mg/l. C_t is the concentration of cadmium ion in solution after the time of as much as t in mg/l, m is the mass of Guava leaves in g, and V is the volume of the solution

3.1 FT-IR studies

From Figures 1 and 2 we notice that band 3423 Cm^{-1} was shifted to 3467 Cm^{-1}, which is for the stretching (OH) group [12]. In Guava leaves and a new band was obtained in 551 Cm^{-1}, because of the adsorption of cadmium in the Guava leaves on the surface.

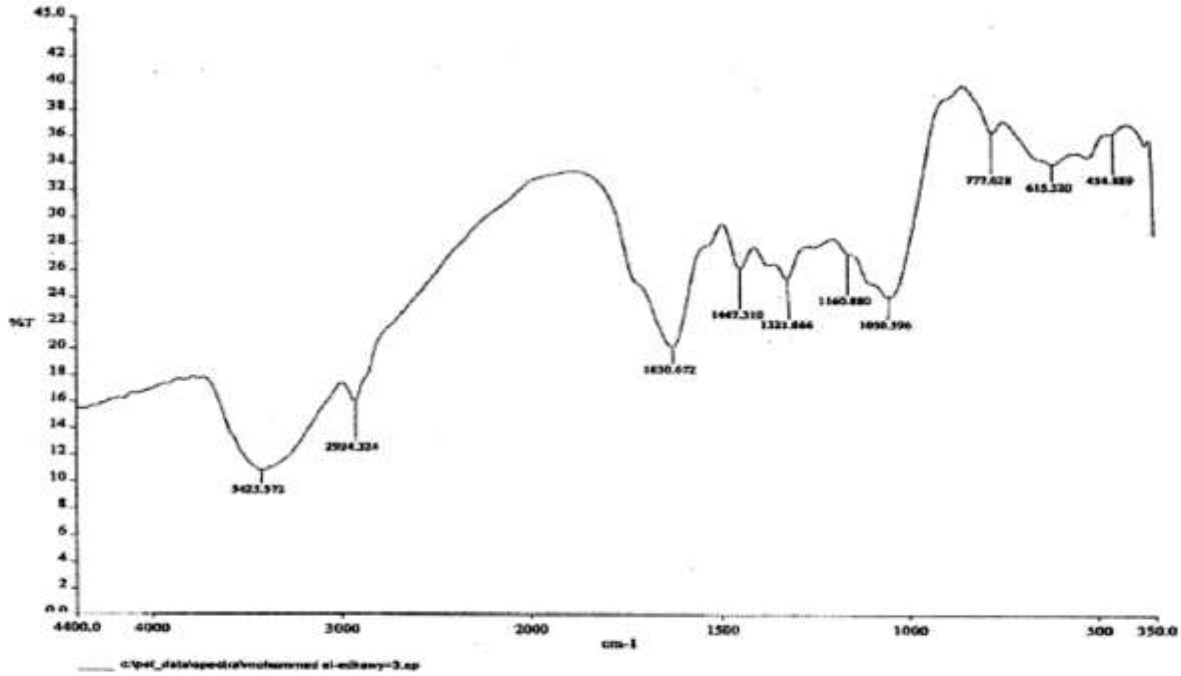

Figure 1: IR spectrum for Guava leaves

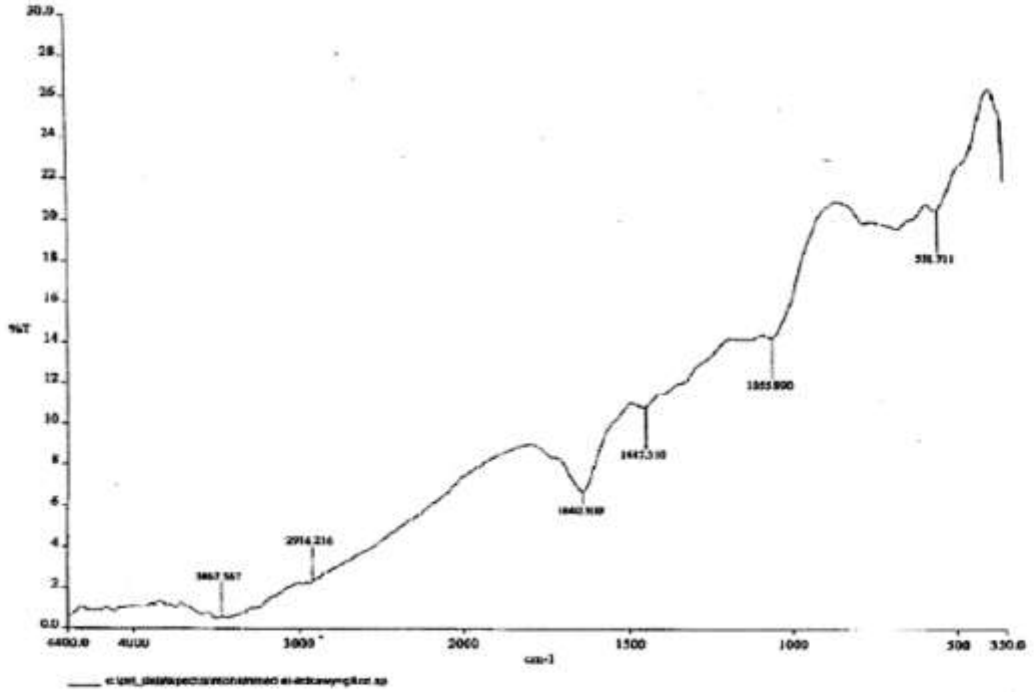

Figure 2: IR spectrum for Guava leaves absorbed Cadmium

3.2 Effect of pH

Figures 3 and 4 show the effect of pH on q_c. Also, the percentage of cadmium removal is shown in Figures 5 and 6 show the change of q_t and %removal with time (120) min at different pH. The graph shows that the adsorption of Cd^{2+}on Guava leaves surface increases in acidic solution at optimum pH=5-6 Generally the positive charges of the adsorbent surface decrease with increasing pH to 7 leading to the decrease in the repulsion between adsorbent and Cd^{2+} (13).

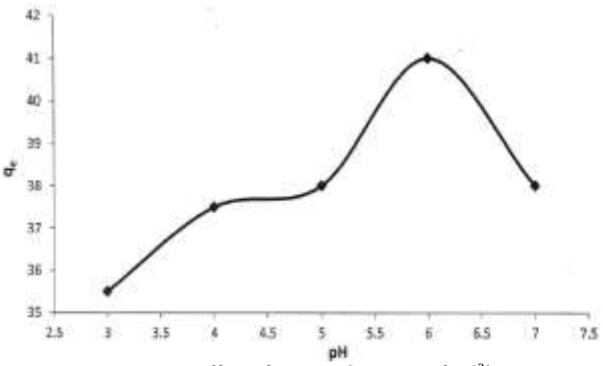

Figure 3: Effect of pH on adsorption of Cd^{2+}

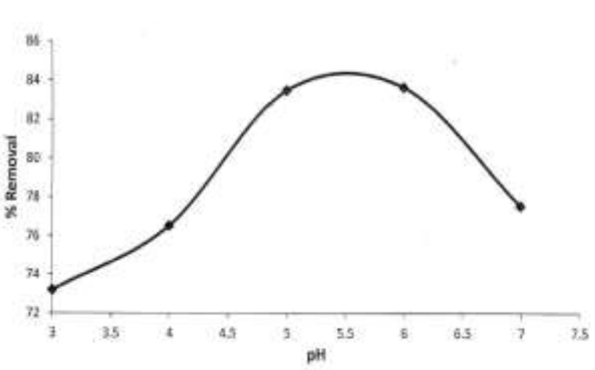

Figure 4: Effect of pH versus Cd^{2+} removal percentage

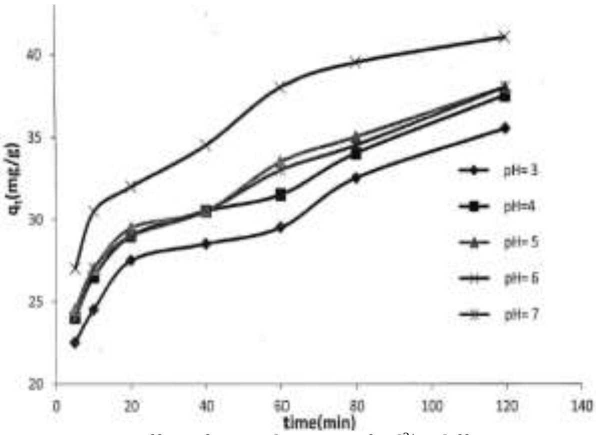

Figure 5: Effect of q_t on adsorption of Cd^{2+}at different pH

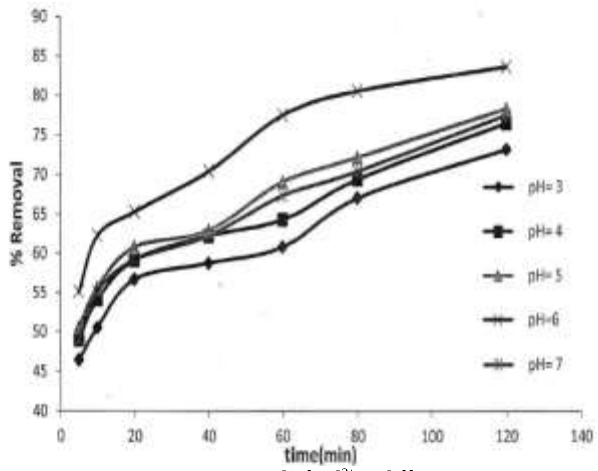

Figure 6 % removal of Cd^{2+} at different pH

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 give an indication 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 that is the contact time characterized by unchanging Cd^{2+} concentration in the solution was achieved after 30 min for all concentrations of solutions; (14) this period is denoted as the second stage of the adsorption. Depending on the concept of adsorption sites we can explain that the vacancy on it at first stage Cd^{2+} could easily interact with these sites. The adsorption capacity was almost constant for all concentrations and such it was considered as the equilibrium time of Cd^{2+} onto guava leaves.

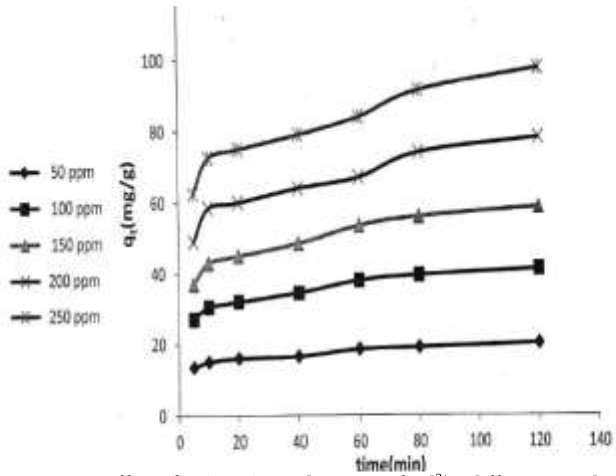

Figure 7: Effect of q_t (mg/g) on adsorption of Cd^{2+}at different initial concentrations

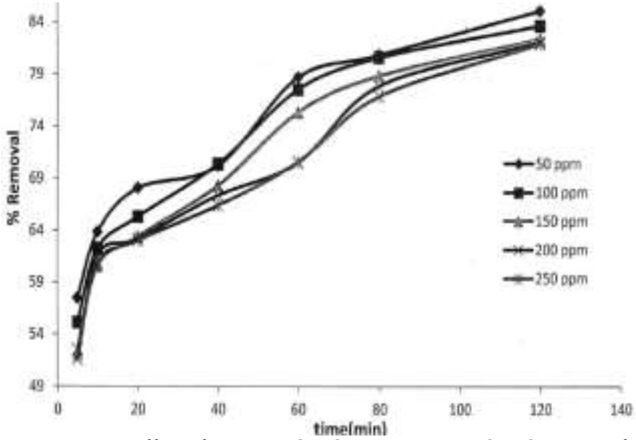

Figure 8: Effect of % removal and contact time on the adsorption of different initial concentrations

3.4 Effect of adsorbent dose

Figures 9 and 10 show that the removal percentage of Cd^{2+} ions increases as the amount of absorbent increases. Absorption increased from 77.55 to 85.56 % with an increase in the absorbent dose from 0.3 to 0.7 g/200 ml. The number of adsorptive sites or surface area increases with increasing the weight of adsorbents which obtain many available exchangeable sites which enhance the percent of metal removal. However, the sorption capacity (q_t) decrease with the adsorbent dose because at a 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 (15-16).

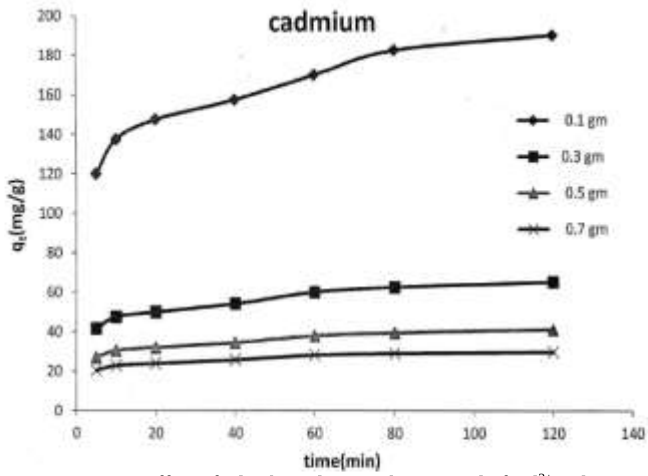

Figure 10: Effect of adsorbent dose on the removal of Cd^{2+} and q_e on the adsorption of different doses of guava leaves

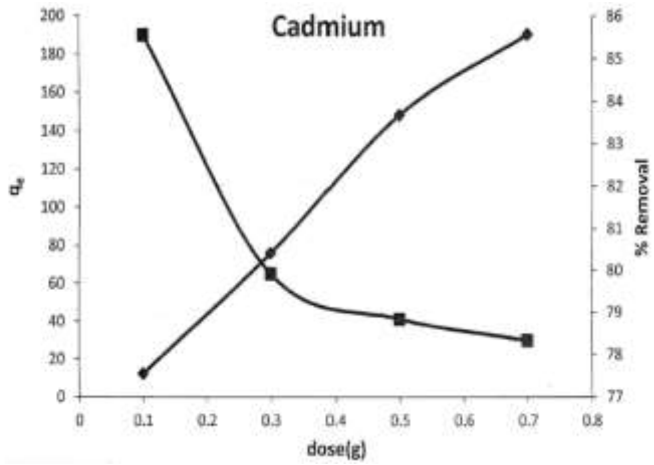

Figure 9: Effect of time on q_t (mg/g) on adsorption of Cd^{2+}

3.5 Effect of speed of rotation on the removal of metals

Figure 11 shows that the speed of rotation enhances Cd^{2+} 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 of transportation of metal ions. The removal of Cd^{2+} reaches 87.75% 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 adsorption capacity of Guava leaves was studied at a constant initial concentration of 100 mg/l and 300 rpm of Cd^{2+}, optimum pH value of 6, and 0.5g/200 ml of Guava leaves Figure 12 and 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 Cd^{2+} and decreasing in 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 Cd^{2+} ions into the pores of the adsorbent at higher (17-22).

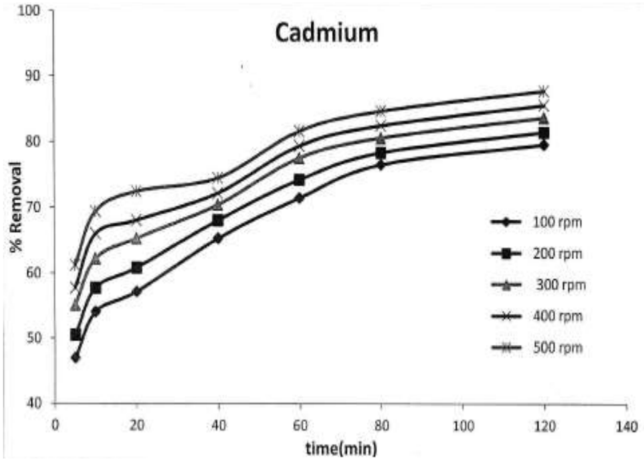

Figure 11: Effect of contact time on the adsorption of Cd^{2+} at different rpm

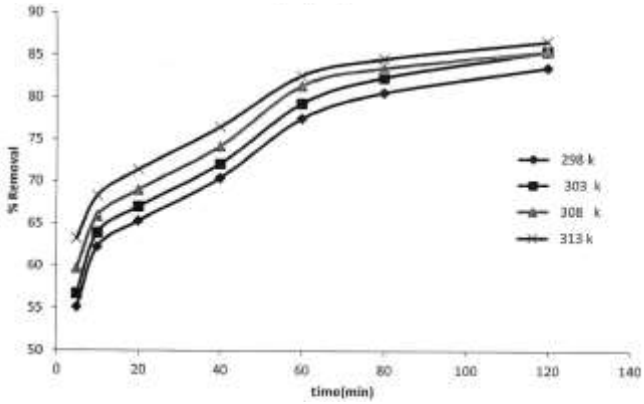

Figure 12: Effect of time on % removal of Cd^{2+} and different temperatures

4 Conclusion

During This work, the investigation of adsorption of metal ions by Guava leaves as a natural adsorbent show the following results. The Guava leaves record an effective percentage removal for the Cd^{2+} metal using 0.5 gm sample size of Guava leaves could remove bout 90% of Cadmium with the initial concentration of 100 ppm within 120 min contact time. Also, a significant increase in the removal of Cd^{2+} could be observed with an increase in the Guava leaves and an increase in the temperature. Time 120 min was the suitable contact time of adsorption. However, the removal rate did not remain the same at other contact times. The optimum pH for the adsorption of Cd^{2+} is found to be in the semi acidic environment (pH around 6). It is obvious that 0.7 gm dose is the most efficient adsorbent dose and the best temperature is 313 K.

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 submitted work is original and has not been published elsewhere in any language. Also, all procedures performed in studies involving human participants were under the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All procedures performed in this study involving animals were following the ethical standards of the institution or practice at which the studies were conducted.

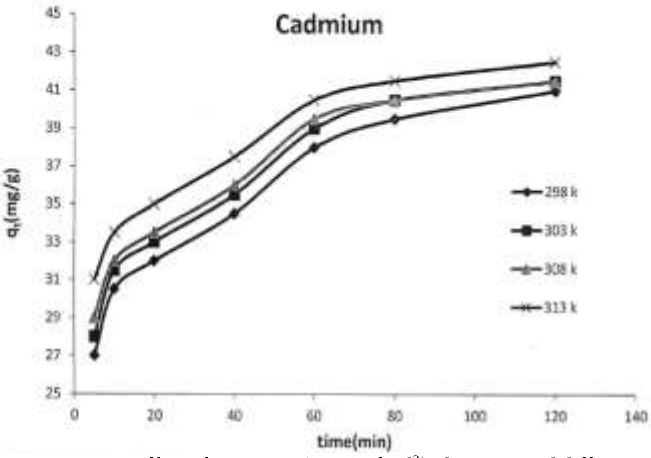

Figure 13: Effect of time on q_t (mg/g) of Cd^{2+} adsorption and different temperatures

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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