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Removal of Cadmium from Wastewater using low cost Natural Adsorbents

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Abstract

Adsorption is one of the effective techniques for heavy metals removal from wastewater. Removal of cadmium ion from aqueous solutions was studied using mixture of low cost material silica gel and calcium carbonate at different mole ratio. Influence of contact time, ph, initial concentration of metal ion, dosage of solid, ratio of SiO_2:$CaCO_3$ and particle size of adsorbent on removal percentage were investigated. Experiments were carried out at room temperature. In present study, the optimum parameters required for maximum adsorption determined as follows: Contact time=120 minutes, pH=9, initial concentration of Cd^{2+}= 105 ppm, ratio of SiO_2:$CaCO_3$= 1:3 adsorbent dosage =100 gm/L.

Keywords: Heavy metals, adsorption, metal removal, cadmium.

Introduction

Due to rapid industrialization and urbanization in developing heavy metal pollution is a serious problem today and its treatment is of special concern due to their recalcitrance and persistence in the environment like organic pollutants, most of these heavy metals do not undergo biological degradation, resulting into harmless end products[1]. Heavy metals are natural components of the Earth's crust, they cannot be destroyed and they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of human body. However, at higher concentration they can lead to poisoning. Heavy metals are dangerous because they tend to bio accumulate. Compounds accumulate in living things at any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, river, lakes and ground water[2].

Many industries release severally toxic heavy metal ions in their wastewaters contaminating natural streams where in disposed, which is a major concern due to toxicity to many life forms[3]. Several conventional methods exist for the removal of heavy metal pollutants from wastewater. These methods include precipitation, electroplating, chemical coagulation, ion-exchange, membrane separation, adsorption, and electro-kinetics etc. However, these methods often incur operational costs[1,4-10]. Adsorption is a highly effective and economic technique for the removal of heavy metals from waste stream. Therefore, eco-friendly and cost effective new technologies are required for the removal of heavy metals from waste steams by appropriate treatment before releasing into receiving water bodies[11]. A low cost adsorbent is one which needs a little processing before use, abundant in nature, a by-product or waste material from another industry. Of course improved sorption capacity may compensate the cost of additional processing [12]. Natural material of certain waste from industrial or agricultural operation is one of the resources for low cost adsorbents. Generally, theses materials are locally and easily available in large quantities. Therefore, they are inexpensive and have little economic value[13].

This paper reports the potential of silica gel and calcium carbonate as low cost adsorbents for removal of Cd^{2+} from aqueous solution. The study includes determination of the best mole ratio of chemical mixture of (silica gel- calcium carbonate), effect of solution pH, effect of initial concentration of metal ion, contact time, dosage of solid and particle size of adsorbent on adsorption.

Material and Methods

Reagents: 1000 ppm Cd^{2+} stock solution was prepared by dissolving 50 mL standard ampoule contains 1 gm bivalent Cadmium in 1 liter deionized water. Other concentrations were obtained by a proper dilution of stock solution.

Apparatus: The following apparatus were used as follows: pH meter (inoLab, pH 7110, Germany). Centrifuge machine (ALL PRO CORPORATION, 800B CENTRIFUGE, India). Atomic Absorption (Phoenix-986 AA Spectrophotometer, England)

Batch studies: All experiments were carried out at room temperature. Batch test was carried out by shaking cadmium solutions with solid at constant agitation speed 250 rpm and after separation by centrifuge, the solution of Cd^{2+} was analyzed by using atomic absorption spectrophotometer. The percent removal of Cd^{2+} was calculated as follow:

% removal of Cd^{2+}= [(C_o- C_e) /C_o]X100

Where: C_o and C_e are the initial and final Cd^{2+} concentrations (ppm) respectively[14].

Results and Discussion

Effect of contact time: The effect of contact time for the efficient removal of metal ion was studied. The Cd^{2+} showed a steady rate increase of sorption during the sorbate-sorbent contact time process and the rate of removal became almost insignificant due to a quick exhaustion of the adsorption sites. The rate of metal removal is higher in the beginning due to a larger surface area of the adsorbent being available for the adsorption of the metal[14]. In this study 98% of Cd^{2+} removal was achieved at 120 minutes. Further, no significant changes were observed in the removal of Cd^{2+} from solution after 4 hours of equilibration. Figure-1 shows contact time effect on removal maximum of 300 ppm Cd^{2+}. Removal increased with time and attains equilibrium after 120 minutes.

Effect of pH: The effect of pH of Cd^{2+} solution on removal efficiency was studied by varying the initial pH under constant process parameters in different ratio of SiO_2:$CaCO_3$. Figure-2 shows that the removal of Cd^{2+} decreased with the increase of pH till pH 5 and 7 at ratio 3:1 and 1:3 (SiO_2: $CaCO_3$) respectively. Then it shows an increase and reaches maximum at pH 9 in both ratios. The maximum sorption was obtained at pH 9, supporting that the sorption is pH dependent[15], surface adsorption is physiochemical phenomenon and the sorption surface contains several activated groups, and these groups have different binding[17].

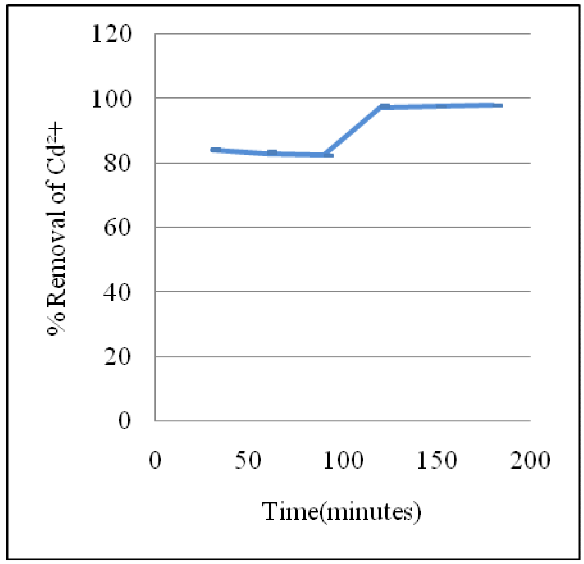

Figure-1
Effect of contact time (minutes) on removal of Cd^{2+} from aqueous solution, [C_o=296 ppm, V= 20 ml, m (Weight of solid)= 2 gm, SiO_2:$CaCO_3$=1:3]

Effect of solid dosage: One of the parameters that strongly affect the sorption capacity is the solid dosage. By varying the solid dosage from 50 to 200 gm/L, it can be easily inferred that the removal percentage of metal ion increases with the increasing weight of solid as shown in figure-3. It can be seen from figure-3 that an adsorbent dose of 2gm (100gm/L) is sufficient for optimal removal of Cd^{2+} in aqueous solutions. This can be explained by greater .availability of the exchangeable sites of surface area at higher amount of the adsorbent.

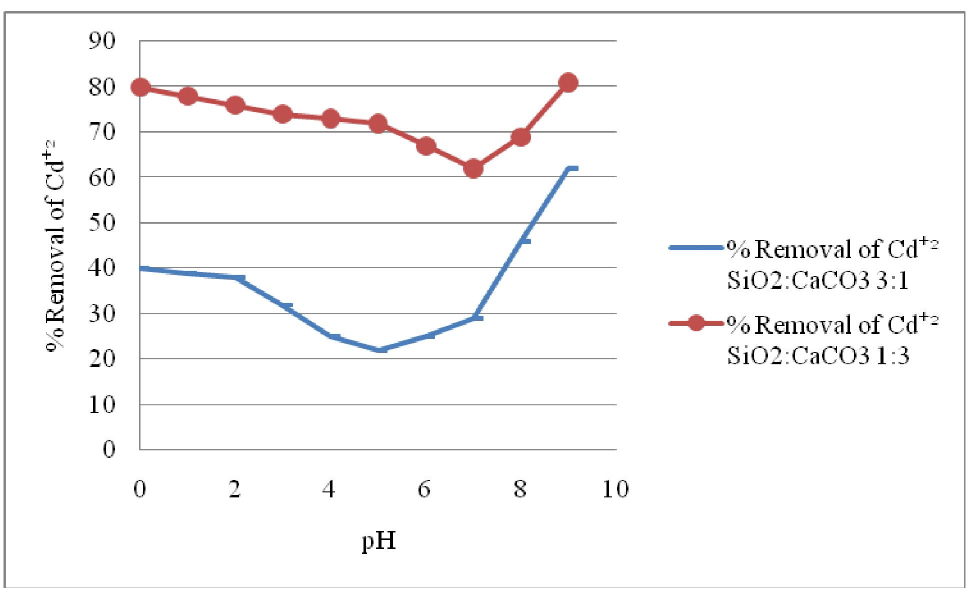

Figure-2
Effect of pH on removal of Cd^{2+} from aqueous solution, [C_o=300 ppm, V= 20 ml, m= 2gm]

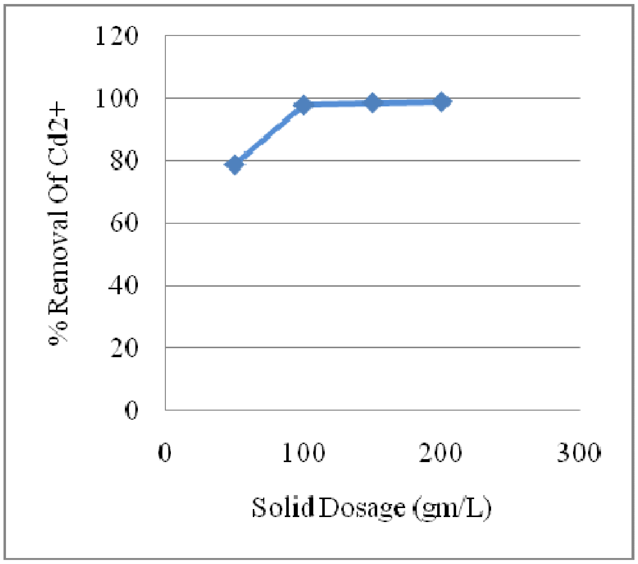

Figure-3
Effect of solid dosage on removal of Cd^{2+} from aqueous solution, [C_o=200 ppm, V= 20 ml, , m= 2 gm, time= 1 hour, SiO_2:$CaCO_3$=1:3]

Effect of metal ion concentration: Figure-4 shows the effect of initial concentrations of Cd^{2+} on the adsorption. The removal efficiency was decreased with increasing of initial concentration of Cd^{2+} (25 – 300) ppm. The study was carried out with SiO_2:$CaCO_3$ ratio of 1:3 and 3:1. The removal efficiency was increased with decrease of cadmium concentrations, which was reached to 100% at 25 mg/L of cd^{2+} in both ratios and decreased at 300 mg/L to 40 % and 80 % for 1:3 and 3:1 ratios respectively. The result indicates that the $CaCO_3$ has a potential to be used as a chief effective ions sorbent for removal of heavy metal ion from solution with high concentration.

Effect of SiO_2:$CaCO_3$ ratio: The experimental runs measuring the effect of SiO_2:$CaCO_3$ ratio on the batch adsorption of Cd^{2+} at initial Cd^{2+} of 300 ppm was shown in figure-5 and it shows that the removal of Cd^{2+} increase with decreasing of the ratio of SiO_2:$CaCO_3$, which means that the calcium carbonate has a potential to be used for removal of heavy metals.

Effect of particle of adsorbent: The effect of solid particle size on the adsorption of Cd^{2+} was shown in figure-6. The adsorption of Cd^{2+} was studied at various particle size of solid ranging from 25 to 200 mesh and Cd^{2+} concentrations 200 and 300 ppm. It was observed that the removal percentage was not affected by the particle size of solid at concentrations of Cd^{2+} (200 and 300 ppm).

Conclusion

From the experiments, it can be concluded that the SiO_2:$CaCO_3$ had the ability to retain Cd^{2+} ion at studied concentrations from aqueous solution as a low cost natural adsorbents. Adsorption process took place for one hour with pH important role especially with adsorption capacity. The main advantage of this study is the ability to apply this adsorption process with this low cost adsorbents mixture to remove heavy metal pollution.

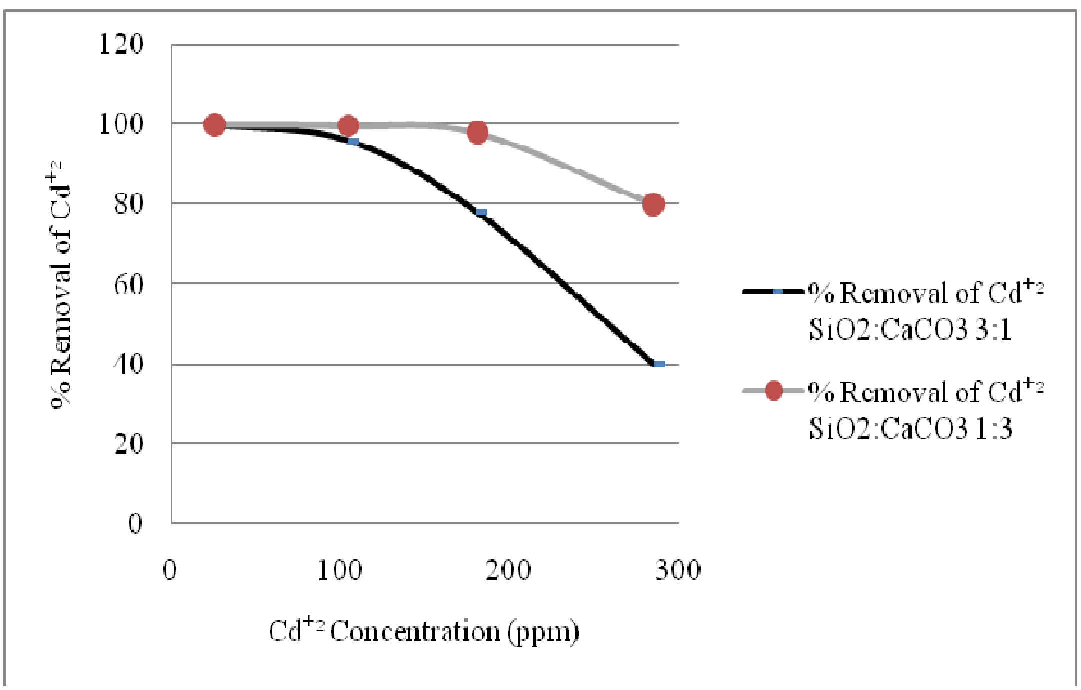

Figure-4
Effect of initial metal ion concentration on removal of Cd^{2+} from aqueous solution [V= 20 ml, , m= 2 gm, time= 1 hour]

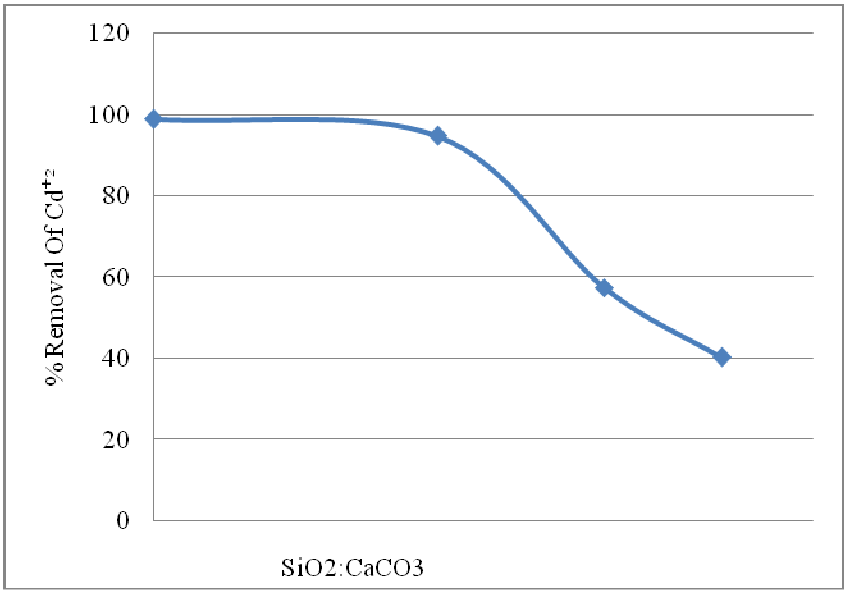

Figure-5
Effect of SiO_2:$CaCO_3$ ratio on removal of Cd^{2+} from aqueous solution, [C_o=300 ppm, V= 20 ml, m= 2 gm, time= 1 hour]

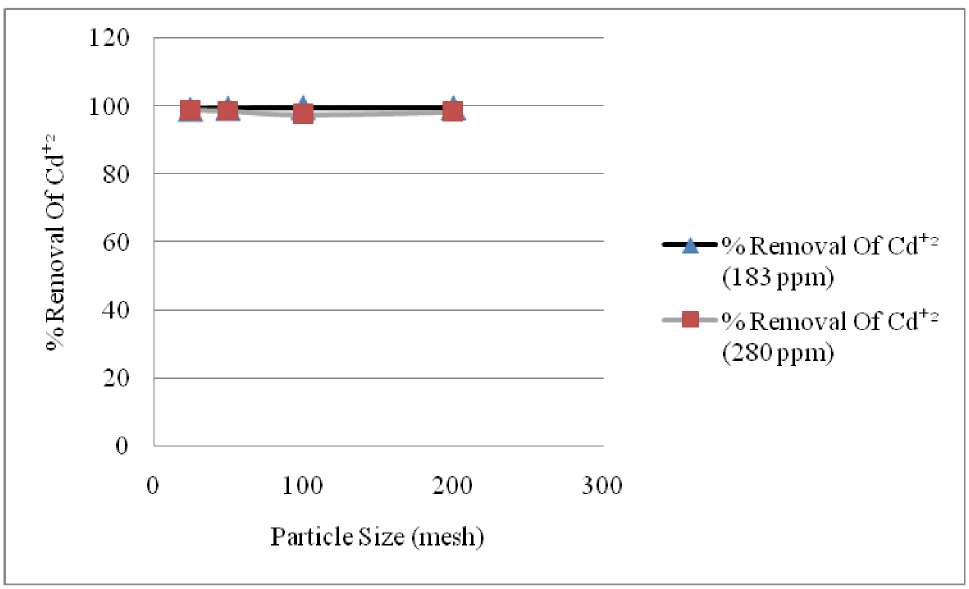

Figure-6
Effect of particle size of solid on removal of Cd^{2+} from aqueous solution
[V= 20 ml, m= 4 gm, time= 1 hour, SiO_2:$CaCO_3$=1:3]

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