

Adsorption of zinc, cadmium and nickel from aqueous solutions using ground water sludge (GWS)

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Abstract

In this study, the applicability of ground water sludge (GWS), a waste material from a ground water treatment plant as a potential absorbent for heavy metals was experimentally analyzed. The presence of 56.4% of Fe_2O_3 in the GWS composition indicated that GWS has potential adsorptive behaviour. An adsorption study using GWS was performed and results were analyzed in the adsorption of several heavy metals namely Ni, Cd, and Zn. The adsorbent concentrations (GWS) were varied from 250 mg/L to 4000 mg/L and agitated with aqueous heavy metal solutions for 1hr, 3hrs, 6hrs and 24hrs contact times. The batch adsorption indicated that Ni, Cd, and Zn were totally adsorbed using 4000 mg/L of the absorbent at a contact time of 24hrs. The removal efficiencies for Cd, Ni, and Zn at adsorbent concentrations of 3000 mg/L, 3500 mg/L and 3500 mg/L, were found to be 91.6%, 73.8% and 69%, respectively. Adsorption of metals also increased with longer contact times and higher adsorbent dosages. The study indicated that there is a potential in using waste sludge from ground water treatment plants as an adsorption material in removing heavy metals.

Keywords: groundwater sludge, adsorption of metals, copper, nickel, zinc.

1 Introduction

Heavy metals removal using adsorption techniques has received a great deal of attention. Various adsorbent materials have been used in removing heavy metals. In this project, ground water sludge (GWS), a waste material from a ground water treatment plant was used as an adsorbent. Approximately five tons of dried



GWS is produced daily from the ground water treatment plant and disposed to a landfill.

Approximately 56.4% of the GWS contains ferum oxide Fe_2O_3 precipitated from the groundwater using aeration and coagulation-flocculation processes.

2 Literature review

Studies on removal of heavy metals through adsorption using different type of materials as an absorbent such as soil biotechnology and hydrous ferric oxide, magnetite-immobilized chitin, and iron coated starfish had been extensively researched. Comparisons of performance between both mineral soil biotechnology (SBT) and hydrous ferric oxide (HFO) in adsorbing As(III) [2] conducted indicate that arsenite removal was favoured by oxidation to As(V) followed by adsorption to the adsorbent. Residual arsenic in water via SBT was below 10 ppb while for HFO's it was lower than 30 ug/L. SBT proved a novel concept to oxidize the As (III) and As (V). Several patent details media, culture and additive that showed complete natural oxidation of As(III) to As(V) and subsequent co-precipitation by iron complex gave residual arsenic less than 10 ug/L conforming to WHO standard for drinking water [3].

Adsorption of Cu^{2+} from aqueous solution by magnetite-immobilized chitin (MC) was conducted on two conventional absorbents, cation exchange resin (CER) and activated carbon (AC) [4]. The parameters measured in the experiment were pH, concentration of absorbent temperature and initial Cu^{2+} concentration. Under the optimized condition, the removal efficiencies of Cu^{2+} using MC, CER and AC were found to be 91.67%, 93.36% and 89.16%, respectively, with maximum adsorption capacities based on Langmuir model of 53.19 mg/g, 89.29 mg/g and 5.82 mg/g, respectively [4]. Various thermodynamic parameters such standard energy (GG), enthalpy (HH) and entropy (SS) were calculated for predicting the adsorption nature of MC. The result indicated that the system was a spontaneous and endothermic process [5].

Use of calcined starfish (SF) and iron coated starfish (ICSF) as absorbent to adsorb toxic heavy metal were able to remove 3,400 mg/kg and 8,600 mg/kg of Cu (II) from wastewater, respectively [6]. From the Langmuir model it was found that the maximum amount of Cu (II) removed by SF and ICSF were 50,900 mg/kg and 82,700 mg/kg, respectively, based on drinking water regulations for Cu(II), SF and ICSF [6]. Although both SF and ICSF have favourable adsorption capacities for Cu(II), ICFS was regarded a better removal and filter material than SF in the treatment of wastewater contaminated with Cu(II) and Pb(II) [6].

Manganese-coated sand (MCS) and iron-coated sand (ICS) have also been used in the adsorption of As (V) with variation of the configuration of MCS and ICS in column experiment [7]. The results indicated that arsenic adsorption followed a typical anionic-type and resulted in complete adsorption of As(V) below pH 7.



3 Methodology

The adsorbent used in the study was groundwater sludge (GWS) produced from a ground water treatment plant. The GWS was prepared by grinding the sludge into fine powered form (100 μm) and dried in the oven to get rid of the moisture at 105°C for one hour. Aqueous metal solutions (Ni, Cd and Zn) of concentrations of approximately 10 mg/L were each prepared from 1000 mg/L metals stock solutions. The adsorbent concentrations used in the adsorption tests were varied at 250 mg/L, 500 mg/L, 750 mg/L, 1000 mg/L, 2000 mg/L, 3000 mg/L, 3500 mg/L and 4000 mg/L in 100 mL of the 10 mg/L metal solutions. For each metal solution, the samples were then shaken using an orbital shaker at contact times of 1, 3, 6 and 24 hours, at 200 rpm. The samples were shaken at temperature of 22 °C. The samples were tested in triplicates. After each contact time, the samples were filtered using the filtration apparatus. The filtrate residual metal concentrations of each sample were measured using Atomic Adsorption Spectrophotometer (AAS).

4 Results and discussion

4.1 Characteristics of GWS

GWS was characterized using X-Ray Diffraction (XRD) and it was found to contain constituents as in Table 1 below. The sludge was brownish-red in colour indicating the presence of high amounts of iron oxide. It can be observed from Table 1 that the highest constituent of GWS is Fe_2O_3 , which is approximately 56.4%.

Table 1: Composition of GWS.

Material	Percentage (%)
Al_2O_3	6.15
SiO_2	16.4
P_2O_5	2.53
K_2O	0.0555
CaO	16.3
MnO	0.310
Fe_2O_3	56.4
SrO	0.0186
BaO	0.193



4.2 Batch adsorption results for zinc (Zn)

The batch adsorption results for zinc at initial concentration of 10.5 mg/L are as shown in Figure 1 below.

It can be observed from Figure 1 that at adsorbent concentrations lower than 3000 mg/L, not much of the zinc is adsorbed at all contact times. However, at contact time of 6 hours, residual zinc removal increased from 19.5% to 69% at adsorbent concentrations of 3000 mg/L and 3500 mg/L, respectively. At 24 hours contact time, the residual zinc removal increased from 17.6% to 38.6% at adsorbent concentrations of 3000 mg/L and 4000 mg/L, respectively. At adsorbent concentration of 4000 mg/L, all the zinc is removed at 24 hours contact time as shown in Figure 2 below.

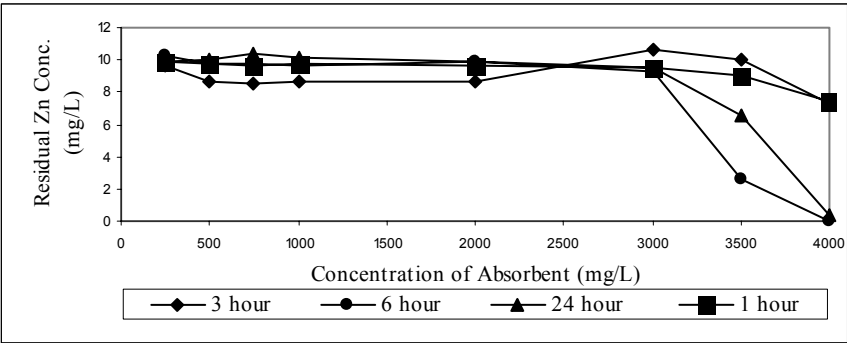


Figure 1: Residual zinc concentration (mg/L) vs. adsorbent dosages (mg/L) at various contact times, hr. ($C_0 = 10.5$ mg/L).

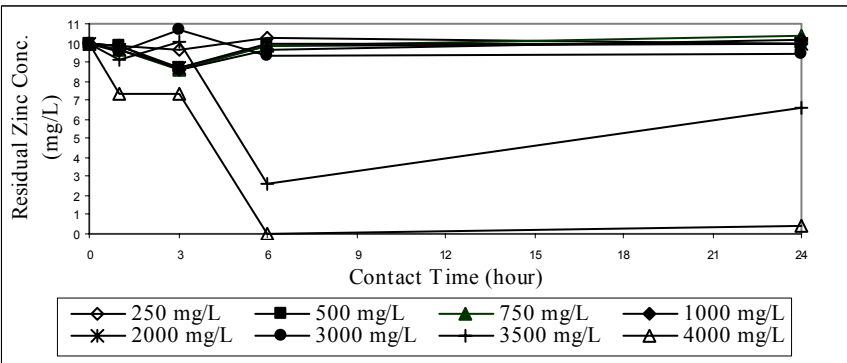


Figure 2: Residual zinc concentration vs. contact times at various adsorbent dosages, $C_0 = 10.5$ mg/L.



4.3 Batch adsorption results for nickel (Ni)

The results of batch adsorption for nickel are plotted as in Figures 3 and 4 below.

It can be observed from Figure 3 that the adsorption of nickel increased with increasing adsorbent dosages. The highest adsorption was obtained at contact time of 24 hours with an adsorbent concentration of 4000 mg/L as shown in Figure 4 below.

The percentage removals of nickel are 44.3%, 62.6%, 79.2% and 82.8%, for adsorbent concentrations of 2000, 3000, 3500, and 4000 mg/L, respectively.

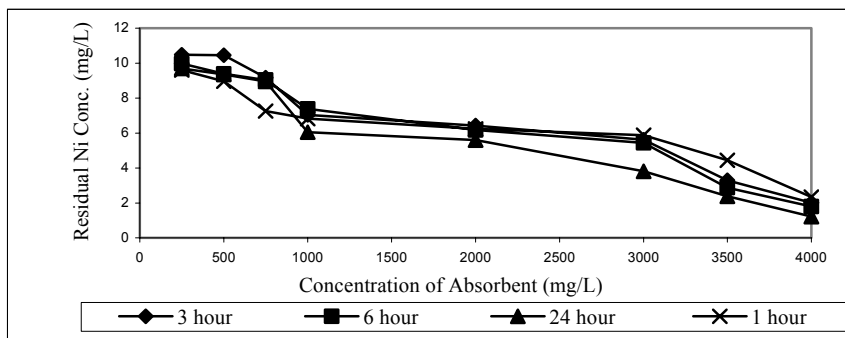


Figure 3: Residual nickel concentration (mg/L) vs. adsorbent dosages (mg/L) at various contact times, hr. ($C_0 = 10.5$ mg/L).

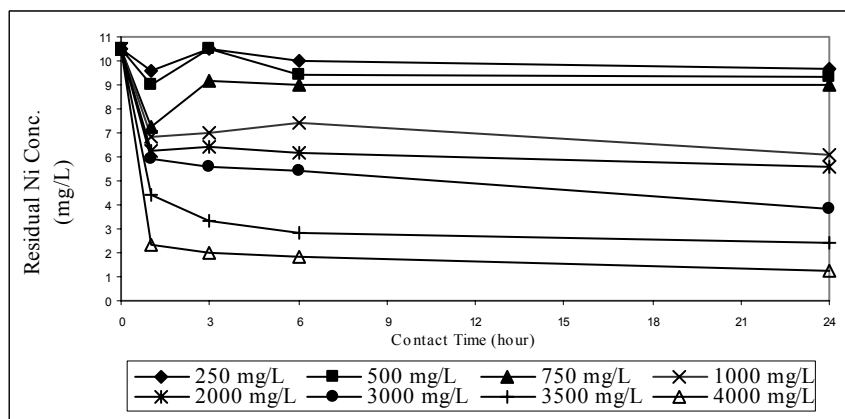


Figure 4: Residual nickel concentration vs. contact times at various adsorbent dosages, $C_0 = 10.5$ mg/L.

4.4 Batch adsorption results for cadmium (Cd)

The batch adsorption results for cadmium are plotted in Figures 5 and 6, at different adsorbent dosages and contact times, respectively.



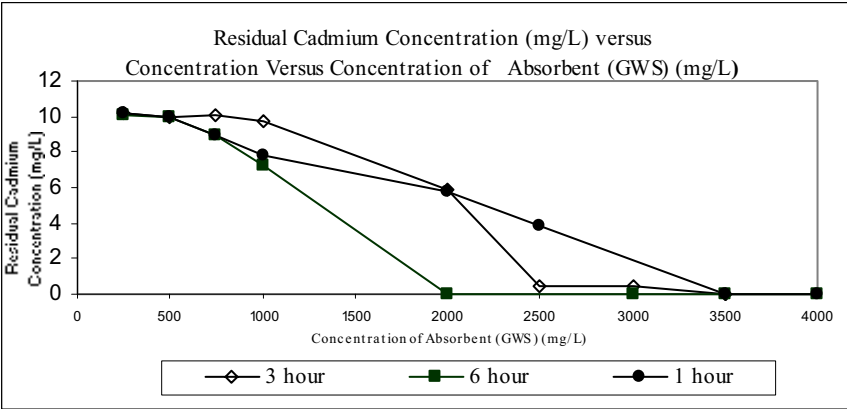


Figure 5: Residual cadmium concentration (mg/l) vs. adsorbent dosages (mg/l) at various contact times, hr. ($C_0 = 10$ mg/L).

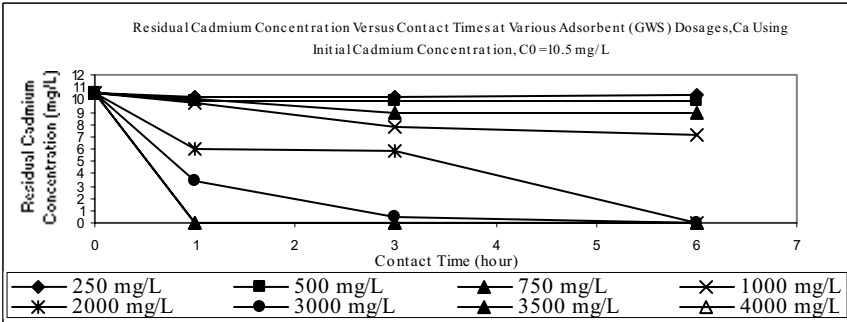


Figure 6: Residual cadmium concentration vs. contact times at various adsorbent dosages, $C_0 = 10$ mg/L.

In Figure 5, it can be observed that at an adsorbent concentration of 2000 mg/L all the cadmium was adsorbed at a contact time of 6 hours. However, at 1 hour contact time, all the cadmium was removed at an adsorbent concentration of 3500 mg/L. Higher removals were obtained with at a higher concentration of adsorbent with a lower contact time. At 1 hour contact time, percentage of cadmium removed increased from 25.6%, 43.1%, 61.1% and 100%, at adsorbent concentrations of 1000, 2000, 3000, and 3500 mg/L, respectively.

In Figure 6, it can be observed that at 6 hours contact time, the residual cadmium was totally removed at an adsorbent concentration higher than 2000 mg/L. Cadmium showed highest removals compared to zinc and nickel, where most of the residual cadmium were removed at 2000 mg/L adsorbent (GWS) concentration. The study was not conducted at a contact time of 24 hours as most of the cadmium was removed at 6 hours contact time.



5 Conclusion

It can be concluded from the adsorption study that Ni, Cd, and Zn were completely absorbed under 4000 mg/L of adsorbent concentration for 24 hrs period. The removal efficiencies for Cd, Ni, and Zn were 91.6, 73.8 and 69.0% at adsorbent concentration of 3000 mg/L (T = 1 hour), 3500 mg/L (T = 24 hour) and 3500 (T = 6 hours) mg/L, respectively. It indicated that GWS, a waste material is capable of adsorbing heavy metals studied and hence has a potential to be recycled into a useful adsorbent for removal of heavy metals.

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