Adsorption and Desorption Studies of Heavy Metals on to Coconut Shell Char

M.S. Abesekara[1], K.N.R. Kosvinna[2], B.M.W.P.K. Amarasinghe*
1)), Department of Chemical and Process Engineering, University of Moratuwa, Moratuwa, Sri Lanka
*B.M.W.P.K. Amarasinghe (*padma@cheng.mrt.ac.lk*)

ABSTRACT
Heavy metals in wastewater can be removed by several methods including adsorption. Activated carbon (AC) is widely used, but expensive adsorbent. Since AC derived from coconut shell (CS) is a good adsorbent, coconut shell char (CSC) as well might be an effective low-cost adsorbent. It was studied the possibilities of using CSC as an adsorbent. Results showed that, CSC has 13% and 12% removal efficiencies for Zn^{2+} and Ni^{2+} from solutions of 50 mg/l. Furthermore, desorption abilities of H_2SO_4, NaOH, Distilled water and NaCl as desorbing agents were analysed and found H_2SO_4 to be the most effective desorbing agent.

Key words: Adsorption, Desorption, Coconut shell char

INTRODUCTION

Heavy metals are one of the most hazardous contaminants released to water bodies by anthropogenic activities. (Burakov et al., 2018). Therefore, various methods have been used to remove heavy metals from aqueous media. However, due to the advantages like low cost, easy operation conditions, wide pH range, high metal binding capacity and reusability of adsorbents, adsorption has become a more preferred treatment method (Barakat, 2011) (Carolin et al., 2017). AC is found to be an efficient adsorbent to remove heavy metal ions due to its porous structure and high specific area. However, utilizing AC is limited in developing countries due to its high preparation cost (Srivastava et al., 2008). Therefore, considering that, AC derived from CSC has good adsorption properties; the study was carried out to check the adsorption ability of CSC. As well as the adsorption ability, desorption properties of CSC were tested with different desorbing agents: H2SO4, NaOH, NaCl and distilled water. The main objective of the study is to evaluate the heavy metal adsorption and desorption properties of CSC while, identifying a suitable desorption agent. Among the most common heavy metals present in the wastewater Ni2+ and Zn2+ are used for the studies.

METHODOLOGY

Material preparation

Preparation of the adsorbent

Required CSC was obtained from a supplier in Gampaha. Washed and dried char was grinded to particles in the range of 500 - 1000 μm. Then, char was washed with tap water followed by distilled water before oven drying at 50 – 60 0C until a constant weight was obtained.

Preparation of solutions

200 mg/l Zn2+ and Ni2+ solutions were prepared by dissolving 1.820 g of analytical grade Zn(NO3)2.6H2O and 1.982 g of analytical grade Ni(NO3)2.6H2O obtained from Sigma Aldrich Corporation in 2 l of distilled water separately. 0.1 M H2SO4, 0.1 M NaOH , 0.5 M NaCl and distilled water were selected as desorption agents. 1 l solutions of each agent were prepared using analytical grade solutions or chemicals.

Adsorption studies

Effect of Initial solute concentration

200 ml of 25, 50 and 100 mg/l Zn2+ and Ni2+ solutions were prepared using 200 mg/l stock solution. Inherent pH of each solution was measured. Each sample was mixed with 2 g of adsorbents at 150 rpm stirrer speed for 2 hours. Finally, sample solutions were filtered using a filter paper and each filtrate was analyzed.

Effect of Contact Time

2 l of 50 mg/l Zn2+ and Ni2+ solutions with an initial pH of 5 were prepared. Each sample was loaded with 19 g and mixed at 150 rpm stirrer speed. 50 ml of samples were withdrawn at time 0, 1, 2, 3, 5, 10 and 20 minutes for the study.

Desorption studies

Used adsorbents were prepared by contacting 1.9 l of 50 mg/l Zn2+ and Ni2+ solutions with 19 g of adsorbents separately. pH, stirrer speed and contacting time was maintained as 5, 150 rpm and 4 hours. After the operation adsorbents were separated by filtration and oven dried at 80 - 100 0C until, the weight becomes constant. 0.1 M H2SO4, 0.1 M NaOH, 0.5 M NaCl and distilled water were used as desorption agents. For 4 g of adsorbent, 100 ml of desorption agent with stirring speed of 150 rpm and 4 hours contacting time.

RESULTS AND DISCUSSION

Adsorption studies

Effect of initial metal ion concentration

According to Figure 1, Ion removal percentage decreases when the initial ion concentration increases for both solutes. The ratio of surface-active sites to the total metal ions in the solution is high in low ion concentrations. Therefore, all metal ions may interact with the adsorbent and be removed from the solution. Moreover, in low concentrations removal of Zn2+ is more effective than Ni2+. Furthermore, as shown in the Figure 2 amount of metal adsorbed per unit weight of adsorbents (adsorption capacity) decreases with increasing initial metal ion concentration. However, for Ni2+, there is no sharp variation as in Zn2+ in adsorption capacity. Ni2+ adsorption capacity is around 0.5 mg Ni2+/ g CSC for any initial metal ion concentration. The reason may be higher electro negativity of Ni^{2+} than Zn^{2+}. Therefore, it readily attached with available anionic

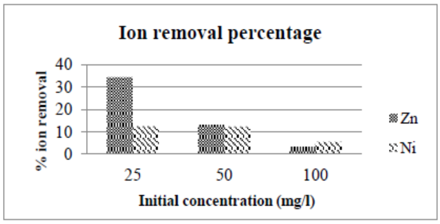


Figure 1 Variation of percentage ion removal with initial ion concentration

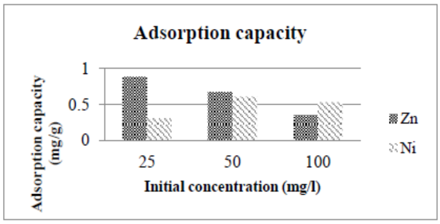


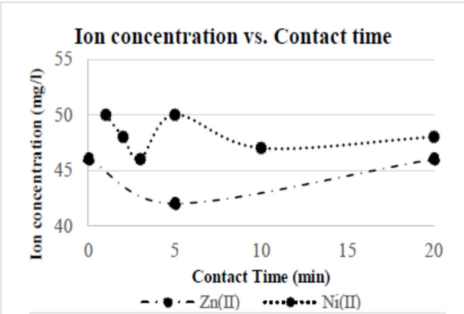
Figure 2 Variation of adsorption capacity with initial ion concentration

functional groups (-OH) on the surface of CSC.

Effect of contact time

Initial concentration of the Zn^{2+} and Ni^{2+} solutions were 47 and 54 mg/l respectively. With time a rapid adsorption can be seen in Zn^{2+} ions in first 5 minutes as shown in Figure 3. However, a sudden desorption, resulted increase of ion concentration within next 15 minutes. Ni^{2+} adsorption kinetics shows a rapid adsorption initially in first three minutes and then desorption become dominant in next few minutes. For final 15 minutes, solution concentration is around equilibrium concentration of corresponding initial ion concentration according above study.

Desorption Studies.



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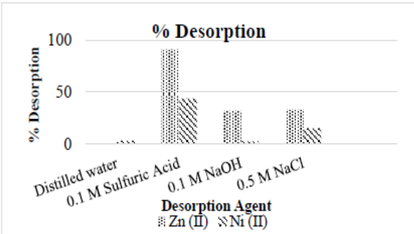

Figure 4 % Desorption for different desorption agent

FTIR Analysis

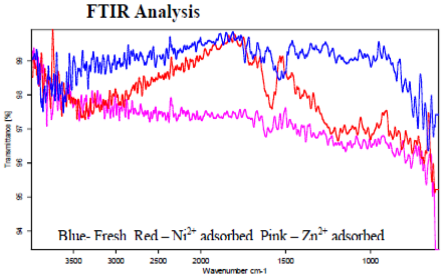

Figure 5 Results of FTIR analysis

As shown in Figure 4, Sulfuric acid is the best desorption agent with 90% and 44% desorption of adsorbed Zn2+ and Ni2+ respectively. It may be due to attraction and strong bond between H+ and OH- ions. Being neutral, distilled water is the poorest desorption agent. According to results it can be identified that more ionic and acidic the agent, desorption ability is higher.

Bands between 3500 – 3000 cm-1 are related to the valence vibrations of the –OH groups. After adsorption, the displacement of vibration bands can be observed for both Zn2+ and Ni2+. It may be due to the formation of chemical bonds between functional groups present in CSC.

CONCLUSIONS

According to the results it can be suggest that high dose CSC is required for effective removal of heavy metals. Because, in commercial scale, percentage ion removal should be at least higher than 80%. Desorption studies emphasis that acids are the most suitable desorption agent. However, AC derived from CS is one of the best commercial AC. Hence study can extend further to examine adsorption characteristic of CSC treated by various chemicals and temperatures.

REFERENCES

Barakat, M. (2011). New trends in removing heavy metals from industrial wastewater. Arabian Journal of Chemistry, 4(4), pp.361-377

Burakov, A., Galunin, E., Burakova, I., Kucherova, A., Agarwal, S., Tkachev, A. and Gupta, V. (2018). Adsorption of heavy metals on conventional and nanostructured materials for wastewater treatment purposes: A review. Ecotoxicology and Environmental Safety, 148, pp.702-712.

Carolin, C., Kumar, P., Saravanan, A., Joshiba, G. and Naushad, M. (2017). Efficient techniques for the removal of toxic heavy metals from aquatic environment: A review. Journal of Environmental Chemical Engineering, 5(3), pp.2782-2799.

Srivastava, V.C., Mall, I.D., Mishra, I.M., 2008. Removal of cadmium(II) and zinc(II) metal ions from binary aqueous solution by rice husk ash. Colloids Surf.Physicochem. Eng. Asp. 312, 172–184