Multicomponent Adsorption of Heavy Metals onto Coconut Shell Char: Kinetic and Equilibrium Study

R. A. C. D. Perera[1], M. H. G. Madushika[2], K. A. D. U. Anupama[3], 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

Coconut shell (CS) charcoal is a potential low-cost adsorbent. Ni(II) and Zn(II) ions in wastewater removal by adsorption is studied in the research using CS char. Results showed that, the maximum adsorption capacity for the Ni(II) ions system was 14.81% in solution of 50 mg/l. The adsorption data for single component systems fitted with Langmuir isotherm and followed pseudo-second order kinetic model. Increase in initial ion concentration reduces the percentage removal in both single component systems. In the multi-component system, the ion removal increases and then decreases. CS char is a somewhat good adsorbent as the removal efficiencies are close to 20%. Higher dosage should be used for better results.

Key words: Adsorption, Coconut shell char, Multicomponent system

INTRODUCTION

Heavy metals are a major contaminant of waste water generated by industries which exhibit toxic properties and persisting behaviour (Bartczak, et al., 2015). There are several methods that are currently in use for the removal of heavy metal ions. However, due to the low cost, easy operation conditions, design simplicity, high metal binding capacity, and reusability of adsorbents, adsorption has become a promising method (Sousa, et al., 2010). Activated carbon is considered as an efficient adsorbent to treat waste water but the cost of AC has limited its usage (Carolin, et al., 2017). Many parts of the coconut tree have been used in adsorption studies. Based on AC derived from CS char has good adsorption characteristics in early studies. The objective is to determine the adsorption ability of CS char for wastewater Ni2+ and Zn2+ single and multicomponent systems. The effect of contact time and the effect of initial ion concentration are investigated to study kinetic and equilibrium behaviour of CS.

METHODOLOGY

Preparation of the adsorbent

Required CS char was obtained from a small-scale local supplier in Gampaha. Washed and dried char was grinded into small particles within the range of 500 μm - 1000 μm. Then, adsorbents were washed with tap water followed by distilled water before drying at 50 – 60 0C until a constant weight was obtained.

Preparation of solutions

200 mg/l Zn^{2+} and Ni^{2+} stock solutions were prepared by dissolving 1.820g of analytical grade $Zn(NO_3)_2$.6H2O and 1.982 g of analytical grade $Ni(NO_3)_2$.6H2O obtained from Sigma Aldrich Corporation in 2 l of distilled water separately.

Effect of Initial ion concentration

200 ml of 25, 50 and 100 mg/l Zn^{2+} and Ni^{2+} solutions were prepared separately by using stock solutions. Inherent pH of each solution was recorded. Each sample was mixed with 2 g of adsorbent at room temperature and 150 rpm stirrer speed for

2 hours. Finally, sample solutions were filtered using a filter paper and each filtrate was analysed.

Effect of Contact Time

2 l of 50 mg/l Zn^{2+} and Ni^{2+} solutions with an initial pH of 5 were prepared and each loaded with 20 g of adsorbent. Adsorption was carried out in room temperature and 150 rpm stirrer speed. 50 ml of samples were withdrawn at time 0, 1, 2, 3, 5, 10 and 20 minutes for the study.

RESULTS AND DISCUSSION

Effect of contact time

According to Figure 1, ion removal percentage of Ni(II) increases and after 10 minutes, percentage removal of nickel does not change significantly. This almost stable behaviour implies the attainment of the equilibrium state. Initially, the adsorbent sites are free. With increase in contact time, surface-active sites are being occupied, only a small increase in metal uptake can be observed.

According to figure 2, the percentage removal has demonstrated the same behaviour as in the single component system. Moreover, Zn(II) ion removal has increased gradually with increase in contact time. After 120 minutes, uptake of Zn (II) ions is significantly higher than Ni(II) ions which implies the Zn(II) removal is more preferred in multicomponent system. This fact is further proved in the studies conducted by Baig, et al. (2009).

Due to the presence of two types of ions, metal uptake is less in the multicomponent system at all contact times. Further, it proves that both metal ions have inhibited each other's ability to attach with functional groups in the competitive adsorption process.

Adsorption kinetics

The kinetic of Ni(II) single system is analysed using pseudo-first order and pseudo-second order kinetic models to find out the rate determining step of adsorption. Ni(II) adsorption is more fitted to pseudo second order kinetic model.

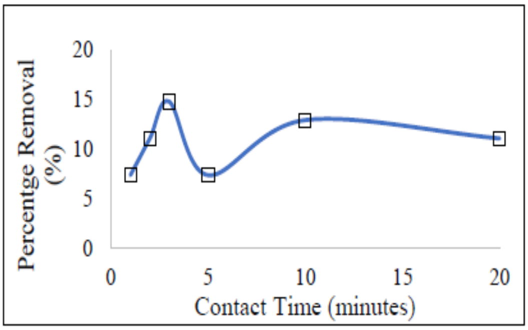

Figure 1 Percentage removal of Ni(II) with contact time

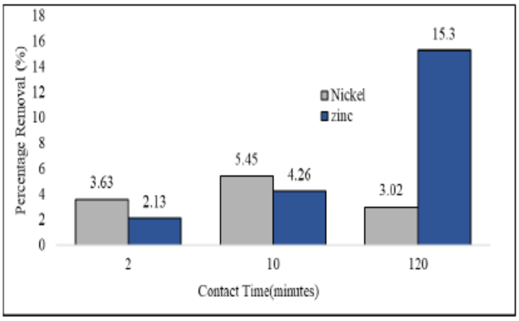

Figure 2 Percentage removal in multicomponent system with time

Effect of initial ion concentration

According to Figure 3, it is observed that the percentage removal of Ni(II) ions and Zn(II) ions have decreased with the increase of initial ion concentration. The maximum percentage removal is observed at the initial ion concentration of 25 mg/l for both ions.

At low concentrations, there is a high surface-active site to metal ions ratio in the solution. So, the removal of ions is high. However, when the ion concentration increases for the same adsorbent dosage, the ratio becomes low. Hence, the percentage removal decreases with the increase of initial ion concentration for both ions in single component systems.

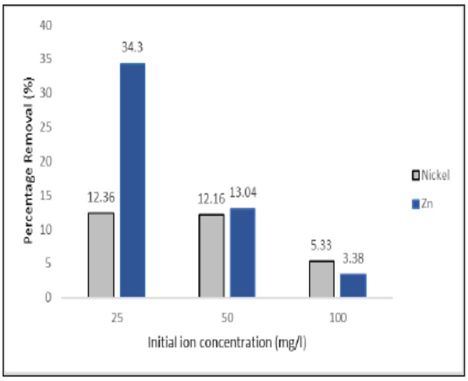

Figure 3 Percentage Removal of Ni(II) and Zn(II) in single component systems with initial ion concentration

As shown in Figure 4, the percentage removal increases initially and then decreases with the increase of initial ion concentrations of multicomponent system. Moreover, the equilibrium uptake of Ni (II) ions is significantly higher compared to Zn (II) ions in initial ion concentrations of 26.45mg/l and 52.9mg/l. The reason for this behavior may be the higher electro negativity of Ni(II) than Zn(II) which allows Ni(II)

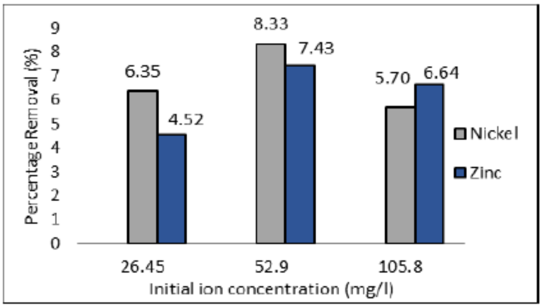

Figure 4 Percentage removal in multicomponent system with initial ion concentration

ions to readily attach with anionic functional groups (-OH) on the surface of coconut shell char. Therefore, at low initial metal ion concentrations Ni(II) removal is more preferred in multicomponent system.

CONCLUSIONS

According to the results obtained, it can be suggested that CS char is a somewhat good adsorbent for the removal of heavy metal ions. To improve the removal percentages, higher dosage of CS char should be used. Furthermore, the study can be extended to examine adsorption characteristic of CS char treated by various chemicals and lower particle sizes.

REFERENCES

Baig, K. S., Doan, H. & Wu, &. J., 2009. Multicomponent isotherms for biosorption of Ni2+ and Zn2+. *Desalination*, 4 10, Volume 249, pp. 429-439.

Bartczak, P., Norman, M., Klapiszewski, Ł. & ska, &. N. K., 2015. Removal of nickel(II) and lead(II) ions from aqueous solution using peat as a low-cost adsorbent: A kinetic and equilibrium study. *Arabian Journal of Chemistry.*

Carolin, C. F. et al., 2017. Efficient techniques for the removal of toxic heavy metals from aquatic environment: A review. *Journal of Environmental Chemical Engineering, Volume 5, pp. 2782-2799.*

Sousa, F. W., Ribeiro, A. G. O. J. P., Morsyleide & Keukeleire, &. D., 2010. Green coconut shells applied as adsorbent for removal of toxic metal ions using fixed-bed column technology. *Journal of Environmental Management, Volume 91, pp. 1634-1640.*