Jurnal
Teknologi

Full Paper

SORPTION OF ZINC USING MICROWAVE INCINERATED SUGARCANE BAGASSE ASH (MISCBA) AND RAW BAGASSE

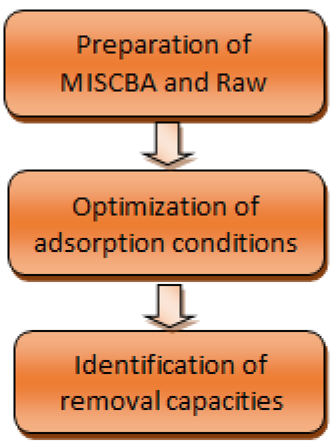
Ibrahim Umar Salihi*, Shamsul Rahman Mohamed Kutty, Mohamed Hasnain Isa, Amirhossein Malakahmad, Usman Aminu Umar

Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS (UTP), 32610, Bandar Seri Iskandar, Perak Darul Ridzuan, Malaysia

Article history
Received
1 June 2015
Received in revised form
5 September 2015
Accepted
4 December 2015

*Corresponding author
salihi37@yahoo.com

Graphical abstract



Abstract

Release of contaminated wastewater containing toxic pollutants has adverse negative effects to the receiving water environment. Heavy metals are non-biodegradable, with longer half –life and overtime, and can accumulate in living organism. Therefore, it is important to remove heavy metals from wastewater for its safe disposal. In this study, activated carbon prepared from thermal incineration of sugarcane bagasse was used in removing zinc from synthetic solution. The prepared carbon is termed as microwave incinerated sugarcane bagasse ash (MISCBA). Raw non-incinerated bagasse was also employed to compare the removal capacities of the two adsorbents (MISCBA and raw bagasse). Parameters including pH, contact time, initial metal concentrations and adsorbents dosages were examined. The results showed that pH of 6.0, contact time 3 hours and adsorbents dosage of 12 g/L were found to be optimum for zinc removal. Removal capacities of 21.05 mg/g and 13.4 mg/g were determined for MISCBA and raw bagasse, respectively. Freundlich correlation coefficients for MISCBA and raw bagasse were found to be 0.7508 and 0.9233, respectively. Langmuir correlation coefficients were 0.9231 and 0.6423, for MISCBA and bagasse respectively.

Keywords: Microwave, zinc, adsorption, bagasse ash, heavy metals

1.0 INTRODUCTION

Heavy metals presences within the environment have continued to trigger serious and difficult problems that consistently attract more attentions in the entire world. Heavy metals are considered to be among the major water pollutants of both ground and surface water sources. Heavy metals toxicity effect on the environment has led to the enactment of stringent standard limits of their discharge into water bodies and open landscapes. Heavy metals differ from other environmental contaminants, as they are not biodegradable, have the ability to accumulate in living organism bodies and found to be toxic or carcinogenic [1].Zinc is an indispensable trace element required by the body. It is an essential trace element needed by microorganisms, animals and plants, for their evolution and development [2]. Vasak and Hasler reported that zinc is the second most available transition metal ion discovered in living organisms, besides iron, being first [3]. Rink *et al.* (2002) noted that, zinc is found to be the only metal which is a cofactor for many over 3000 enzymes, and plays an important role towards calming of the structures of a large amount of proteins, involving signaling enzymes at every level of cellular signal transduction and other factors like transcription [4]. However, release of zinc into the receiving bodies of water at an elevated concentrations can lead to intense toxicological effects on humans and other aquatic ecosystem [5]. Therefore, it becomes important to treat zinc from industrial wastewater before discharging it into the environment.

Adsorption proved to be one of the most effective techniques for treatment of metal bearing effluent wastewater compared to other treatment techniques [6]. Commercial activated carbon is the most effective and widely used adsorbent for heavy metals removal from wastewater through adsorption process [7]. The phrase activated carbon was derived from the word "carbon" and "active", the carbon term refers to a raw material carbonize at high activation temperature while active refers to a carbon material that undergoes an activation process in order to open its pore surface area to made them active for maximum adsorption of pollutants from a liquid phase. However, the finer the activated carbon, the more costly it becomes [8].

In recent years, the use of low cost waste material as an alternative to commercial activated carbon has been stimulated [9]. Waste materials from agricultural by-products have been extensively utilized to produce an alternative adsorbent [10]. Agricultural by-products explored includes fly ash [11], rice husk [12], sawdust [13], sugarcane bagasse [10, 14], banana leaves [15], citrus peel off [16], peanut shell [17], pineapple waste [18] etc.

In this study, another alternative activated carbon was used which produced through thermal treatment of sugarcane bagasse through microwave incineration to produce microwave incinerated sugarcane bagasse ash (MISCBA). Then, its adsorption capacity was compared with raw sugarcane bagasse, for zinc removal.

2.0 EXPERIMENTAL

2.1 Preparation of Adsorbent

Raw sugarcane bagasse was obtained from night market in Seri Iskandar, Malaysia. The bagasse was cut to 10 cm size and washed extensively with tap water to eliminate trapped and ligneous contaminations. In order to achieve further purity, bagasse was washed several times with distilled water for decontamination purpose.

Clean bagasse was dried in an oven for 24 hours at 105°C until constant weight was achieved. The dried sample was further cut to a size of 5 cm and was subjected to microwave furnace (OTF-1200X-S50-LVT) incineration at an activation temperature of 900 °C, heating rate of 11 °C/min and residence time of 3 hours. The resulting product microwave incinerated sugarcane bagasse ash (MISCBA) was made into fine powder size of about 150 µm. MISCBA was immersed in a weak acid (1%, pH 4.57) to keep it in acidic state. Finally, it was filtered and dried under room temperature. The dried sample was stored in an airtight container for further studies.

2.2 Preparation of Adsorbate

Zinc stock solution of 1000 mg/L was prepared by dissolving its corresponding salt in 1000 mL deionized water to form a synthetic wastewater. Further concentrations were achieved by diluting the stock solutions. All chemicals were of analytical grade and obtained from Merck (Germany).

2.3 Experimentation

Batch adsorption studies were carried out using series of Erlenmeyer flask containing 100 mL of synthetic solution with 0.5 g dosage of either MISCBA or raw bagasse. The flasks were agitated using orbital shaker (Protech model 722) at 150 rpm and at room temperature of (27±1 °C) until equilibrium were attained. At predetermined time interval, reaction mixtures were filtered using Whatman's glass microfiber filters having a diameter of 47 mm, filtered solutions were analysed for its metal content using Atomic Adsorption Spectrometer, AAS (Model AA 6800 Shimadzu).

Effect of pH was studied by varying pH range from 1 to 8. Adjustment of pH was achieved using1.5 N sodium hydroxide solution or 2.0 N hydrochloric acid solutions. Measurement of pH was carried out using pH meter (model EW 53013, Hach Sension 1). 250 mL Erlenmeyer flasks were used. 100 mL of zinc solution was poured into the flasks containing 0.5 g of either MISCBA or raw bagasse. The flasks were clamped and shaken at 150 rpm for 3 hours. Effect of initial metal concentrations was studied by varying concentration of zinc from 10 to 100 mg/L while keeping pH at optimum value. Experiment was also conducted to study the effect of varying adsorbent dosage on zinc adsorption by both adsorbents; dosage was varied from 0.2 to 1.6 g. Zinc removal efficiency (*R*) and adsorption capacity (*q*) was calculated using the Eq. 1 and Eq. 2.

$$R = \frac{(C_i - C_e)}{C_i} \times 100\% \qquad (1)$$

where, R is the removal efficiency (%), C_i and C_e are initial and equilibrium zinc concentrations in (mg/L)

$$q = \frac{(C_i - C_e)V}{W} \qquad (2)$$

where, q is the adsorption capacity (mg/g), V is the volume of the solution in L, W is the adsorbent weight (g), C_i and C_e are initial and equilibrium metal concentrations in mg/L.

2.4 Isotherm Studies

2.4.1 Freundlich Isotherm Model

Freundlich isotherm model is a widely used model to describe equilibrium of adsorption having an equation in empirical form. Freundlich isotherm model has the ability of unfolding adsorption related to both organic and inorganic composites on a wider range of adsorbents inclusive of biosorbent [19]. Freundlich isotherm model can be written in the form of Eq. 3.

$$\log q_e = \log K_F + \frac{1}{n}\log c_e \tag{3}$$

where, log qe is the amount of adsorbate adsorbed per unit weight of adsorbent (mg/g), K_F is a Freundlich constant. Plot of log qe against log C_e has $1/n$ as a slope and log K_F as its intercept.

2.4.2 Langmuir Model Isotherm

Langmuir model is another widely used model to describe sorption of heavy metals by biosorbent. Langmuir model operates based on three distinct assumptions: all surface areas are the same and can occupy one adsorbed atom. it is limited to monolayer coverage adsorption and capability of a molecule adsorbed at a given site is not dependent on the occupancy of its adjoining sites [19]. Eq. 4 represents Langmuir isotherm model.

$$\frac{c_e}{x/m} = \left(\frac{1}{ab}\right) + c_e\left(\frac{1}{a}\right) \tag{4}$$

where, C_e is the concentration at equilibrium (mg/L), and x/m is the amount of adsorbate adsorbed per actual amount of adsorbent (mg/g), a and b are constant. Plot of C_e /x/m against Ce must be linear line having a slope of $1/a$ and intercept of $1/ab$.

3.0 RESULTS AND DISCUSSION

3.1 Effect of pH

Acidity or alkalinity of a solution is the major steering power that controls metals adsorption capacity by adsorbent [20, 21]. Solution pH greatly affects the metal ions solubility, adsorbent ionization level in relation to reaction and adsorbents functional group counter concentration. Figure 1 shows the effect of pH on zinc adsorption by the adsorbents. Zinc removal efficiency increased with increase of pH in solution. It has been observed that adsorption is unfavourable and weak at lower pH value. This is due to the competition between metal ions and the positively charge hydrogen ions for an active site of the adsorbent [22]. Zinc precipitation as $Zn(OH)_2$ starts at pH value greater than 7.0. Optimum pH value of 6.0 was considered for both MISCBA and raw bagasse with removal efficiencies of 89.0% and 69.6%, respectively. The result is in accordance with Mirzal *et al*. [23].

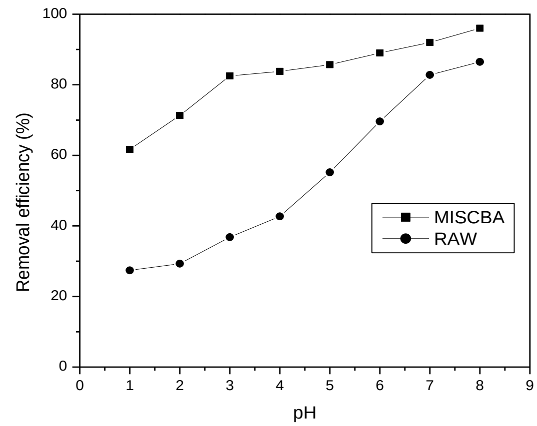


Figure 1 Effect of pH for zinc adsorption onto MISCBA and raw bagasse (initial metal conc: 10 mg/L, dosage: 0.5 g, time: 180 mins, speed: 150 rpm, temperature: 27±1°C)

3.2 Effect of Contact Time

Study on the effect of contact time on the adsorption of zinc by both adsorbents has been carried out. Figure 2 represents the result obtained. Higher removal efficiency was observed at the first 5 to 20 mins and no further substantial removal was realized after 180 mins. The higher removal efficiency is believed to be related with the availability of more surface areas of the adsorbents. However, as the agitation time increased, the surface of the adsorbents tends to worn out of available pore areas. Contact time of 180 mins and 210 mins with removal efficiencies of 91.0% and 78.3%, has been considered to be optimum for MISCBA and raw bagasse, respectively. The result is in accordance with Isa *et al*. [24].

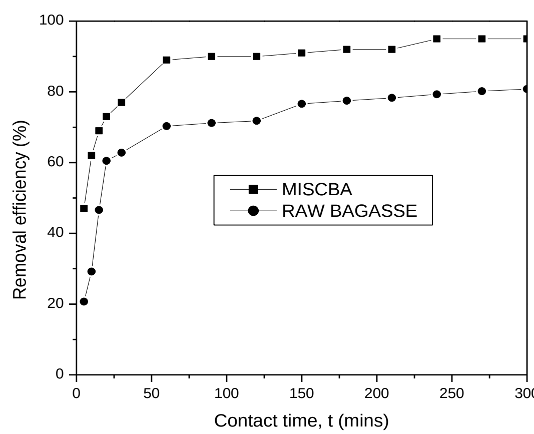


Figure 2 Effect of contact time on the adsorption of zinc onto MISCBA and raw bagasse (initial metal conc: 10 mg/L, speed: 150 rpm, pH: 6, dosage: 0.5 g and temperature: 27±1°C)

3.3 Effect of Initial Metal Concentration

The initial metal concentration of a solution is a parameter that controls the uptake resistance movement between the adsorbent and the adsorbate [13]. It has been observed that removal efficiency was higher at lower concentration level and vice versa. This might be due to the transport of diluted contaminant from liquid to solid phase is easier compared to its concentrated form. Figure 3 indicates that adsorption of zinc depends on the concentration of the solution.

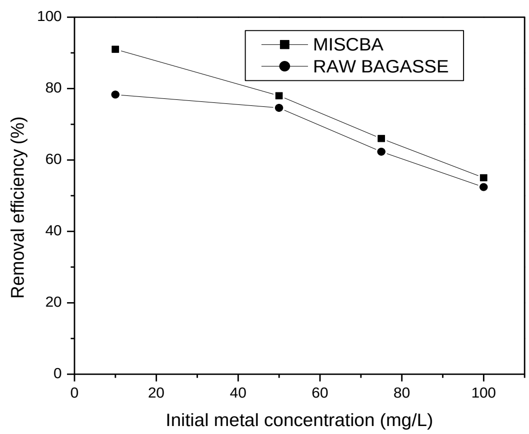


Figure 3 Effect of initial metal concentration on the adsorption of zinc into MISCBA and raw bagasse (contact time: 180 mins, speed: 150 rpm, dosage: 0.5g, temperature: 27±1°C)

3.4 Effect of Adsorbent Dosage

Figure 4 illustrates the results obtained in the study of the effect of adsorbent dosage on the removal zinc for both adsorbents. It was observed that zinc removal efficiency continues to increase until it reaches equilibrium, where no more significant removal can be obtained. As the adsorbent dosage is increased, more surface area is available for the adsorption of zinc. At the equilibrium point, removal efficiencies of the adsorbents were found to be 97.3 and 71.5% for MISCBA and raw bagasse, respectively.

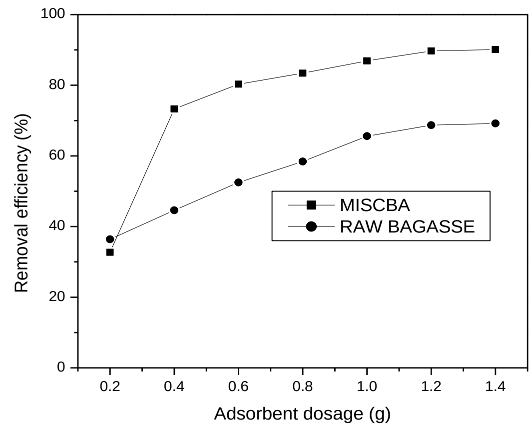


Figure 4 Effect of adsorbent dosage on the adsorption of zinc into MISCBA and raw bagasse (initial metal conc: 100 mg/L, time: 180 mins, speed: 150 rpm, pH: 6.0 and temperature: 27±1°C)

3.5 Adsorption Isotherms

Adsorption behaviour between an adsorbent and adsorbate can be portrayed better through isotherm studies. Langmuir and Freundlich isotherm models were used as tools to study the behaviour of zinc adsorption by the adsorbents. Table 1 shows the isotherm constants obtained from the linear plots of the adsorbents.

Table 1 Langmuir and Freundlich adsorption isotherm constants

Isotherm models	constants	MISCBA	Bagasse
Langmuir	Qo	21.05	13.4
	b	0.06	0.009
	R^2	0.9231	0.6423
Freundlich	K_F	2.68	57.2
	n	2.06	0.61
	R^2	0.7508	0.9233

Adsorption using MISCBA can be well described using Langmuir isotherm model than Freundlich and vice versa, in the case of raw bagasse. Removal capacities of the adsorbents used were calculated to be 21.05 mg/g and 13.4 mg/g for MISCBA and bagasse, respectively. With a value of $n > 1$ for MISCBA adsorbent, indicates a favourable adsorption coupled with heterogeneous adsorbent surface. The result is in accordance with Pereira *et al* [25].

4.0 CONCLUSION

The findings in this study have shown that improvement of MISCBA through thermal treatment has enhanced its adsorption capacity when compared to raw sugarcane bagasse. The corresponding adsorption capacities were found to be 21.05 mg/g and 13.4 mg/g for MISCBA and raw bagasse, respectively. Removal isotherm for MISCBA and bagasse can be described well by Langmuir and Freundlich isotherm models. Maximum contact time of 3 hours, pH of 6.0 and adsorbent dosage of 12 g/L were found to be optimum condition for the removal of zinc by the adsorbents.

Acknowledgement

The authors wish to acknowledge Ministry of Education (MOE), Malaysia for the Fundamental Research Grant Scheme (No. 0153AB-I60) to support this study. We wish to also extend our profound gratitude to Miss Yusyawati Bnt Yahaya who has work hard in operating the atomic adsorption spectrophotometer. Our immense appreciation goes to Universiti Teknologi PETRONAS (UTP) for providing a conducive and enabling working environment for this research work.

References

[1] Fu, F. and Wang, Q. 2011. Removal Of Heavy Metal Ions From Wastewaters: A Review. *Journal of Environmental Management*. 92: 407-418.

[2] Chasapis, C. T., Loutsidou, A. C., Spiliopoulou, C. A., and Stefanidou, M. E., 2012. Zinc And Human Health: An Update. *Archives Of Toxicology*. 86: 521-534.

[3] Vašák, M. and Hasler, D. W. 2000. Metallothioneins: New Functional And Structural Insights. *Current Opinion In Chemical Biology*. 4: 177-183.

[4] Beyersmann, D. 2002. Homeostasis And Cellular Functions Of Zinc. *Materialwissenschaft Und Werkstofftechnik*. 33: 764-769.

[5] Amuda, O., Giwa, A., and Bello, I. 2007. Removal Of Heavy Metal From Industrial Wastewater Using Modified Activated Coconut Shell Carbon. *Biochemical Engineering Journal*. 36: 174-181.

[6] Umar, S. I., Kutty, S. R. M., Isa, M. H., Aminu, N., Henry, E., and Rahim, A. F. B. A. 2015. Biomass As Low-Cost Adsorbents For Removal Of Heavy Metals From Aqueous Solution: A Review Of Some Selected Biomass. *InCIEC 2014*. ed: Springer. 973-987.

[7] Huang, C. and Blankenship, D. 1984. The Removal Of Mercury (II) From Dilute Aqueous Solution By Activated Carbon. *Water Research*. 18: 37-46.

[8] Annadurai, G., Juang, R., and Lee, D. 2003. Adsorption Of Heavy Metals From Water Using Banana And Orange Peels. *Water Science & Technology*. 47: 185-190.

[9] Kumar, P., Rao, R., Chand, S., Kumar, S., Wasewar, K., and Yoo, C. K. 2013. Adsorption Of Lead From Aqueous Solution Onto Coir-Pith Activated Carbon. *Desalination and Water Treatment*. 51: 2529-2535.

[10] Salihi, I., Kutty, S., Isa, M., Aminu, N., and Ezerie, H. 2014. Microwave Incinerated Sugarcane Bagasse Ash (MISCBA) As A Low Cost Adsorbent For The Removal Of Zinc In Aqueous Solution. *Energy and Sustainability V*. 186: 281.

[11] Ferrero, F. and Gaglia, Prati M. 1996. Coal Fly Ash And Alginate For The Removal Of Heavy Metals From Aqueous Solutions. *Annali Di Chimica*. 86: 125-132

[12] Kutty, S. R. M., Khaw, S. G., Lai, C. L., Isa, M. H. 2012. Removal of Copper Using Microwave Incinerated Rice Husk Ash (MIRHA) in Continuous Flow Activated Sludge System. *2012 International Conference on Civil, Offshore & Environmental Engineering (ICCOEE2012)*.

[13] Rafatullah, M., Sulaiman, O., Hashim, R., and Ahmad, A. 2009. Adsorption Of Copper (II), Chromium (III), Nickel (II) And Lead (II) Ions From Aqueous Solutions By Meranti Sawdust. *J Hazard Mater*. 170: 969-77.

[14] Salihi, I. U., Kutty, S. R. M., Isa, M. H., Olisa, E., and Aminu, N. 2015. Adsorption Of Copper Using Modified And Unmodified Sugarcane Bagasse. *International Journal of Applied Engineering Research*. 10: 40434-40438.

[15] Krishni, R., Foo, K., and Hameed, B. 2013. Adsorptive Removal Of Methylene Blue Using The Natural Adsorbent-Banana Leaves. *Desalination And Water Treatment*. 1-9.

[16] Gönen, F. and Serin, D. S. 2014. Adsorption Study On Orange Peel: Removal Of Ni (II) Ions From Aqueous Solution. *African Journal of Biotechnology*. 11: 1250-1258,

[17] Ahmad, M., Lee, S. S., Oh S.-E., Mohan, D., Moon, D. H., Lee, Y. H., *et al*. 2013. Modeling Adsorption Kinetics Of Trichloroethylene Onto Biochars Derived From Soybean Stover And Peanut Shell Wastes. *Environmental Science and Pollution Research*. 1-10.

[18] Rosmi, M., Azhari, S., and Ahmad, R. 2014. Adsorption of Cadmium from Aqueous Solution by Biomass: Comparison of Solid Pineapple Waste, Sugarcane Bagasse and Activated Carbon. *Advanced Materials Research*. 832: 810-815.

[19] Febrianto, J., Kosasih, A. N., Sunarso, J., Ju, Y.-H., Indraswati, N., and Ismadji, S. 2009. Equilibrium And Kinetic Studies In Adsorption Of Heavy Metals Using Biosorbent: A Summary Of Recent Studies. *Journal of Hazardous Materials*. 162: 616-645.

[20] Badmus, M., Audu, T., and Anyata, B. 2007. Removal of Lead Ion From Industrial Wastewaters By Activated Carbon Prepared From Periwinkle Shells (Typanotonus fuscatus). *Turkish J. Eng. Env. Sci*. 31: 251-263.

[21] Hashem, M. A. 2007. Adsorption Of Lead Ions From Aqueous Solution By Okra Wastes. *International Journal of Physical Sciences*. 2: 178-184.

[22] Matheickal, J. T. and Yu, Q. 1999. Biosorption Of Lead (II) And Copper (II) From Aqueous Solutions By Pre-Treated Biomass Of Australian Marine Algae. *Bioresource Technology*. 69: 223-229.

[23] Marzal, P., Seco, A., Gabaldon, C., and Ferrer, J. 1996. Cadmium And Zinc Adsorption Onto Activated Carbon: Influence Of Temperature, Ph And Metal/Carbon Ratio. *Journal Of Chemical Technology And Biotechnology*. 66: 279-285.

[24] Isa, M. H., Ibrahim, N., Aziz, H. A., Adlan, M. N., Sabiani, N. H. M., Zinatizadeh, A. A. L., *et al*. 2008. Removal Of Chromium (VI) From Aqueous Solution Using Treated Oil Palm Fibre. *Journal of Hazardous Materials*. 152: 662-668.

[25] Pereira, F. V., Gurgel, L. V. A, and Gil, L. F. 2010. Removal Of Zn2+ From Aqueous Single Metal Solutions And Electroplating Wastewater With Wood Sawdust And Sugarcane Bagasse Modified With EDTA Dianhydride (EDTAD). *Journal of Hazardous Materials*. 176: 856-863.