Cu adsorption in fixed bed column with three different influent concentration

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Abstract. Heavy metals from the electroplating wastewater might cause environmental pollution if not well treated. Generally, carbon adsorption might be used for the final step for further trace metals removal. This study investigated the heavy metal Cu adsorption in the fixed bed column with 1, 10 and 100 mg/L influent concentration. Results showed that K_{AB} decreased as influent Cu concentration increased from 1 to 100 mg/L while N_0 increased as influent concentration increased from 1 to 100 mg/L as can be found in Adams-Bohart model. R^2 was found between 0.8579 and 0.9182. In Thomas model. K_{TH} and q_0 showed the similar trend as K_{AB} and N_0 in the Adams-Bohart model. K_{TH} decreased as influent Cu concentration increased from 1 to 100 mg/L. q_0 increased as influent Cu concentration increased from 1 to 100 mg/L. R^2 of regression model was found between 0.9065 and 0.9836. In Yoon-Nelson model. K_{YN} increased as influent Cu concentration increased from 1 to 100 mg/L while τ decreased as influent Cu concentration increased from 1 to 100 mg/L. Results showed that the three models of Adams-Bohart model, Thmoas model and The Yoon-Nelson model were suitable for the description of Cu adsorption by activated carbon.

1 Introduction

Heavy metals such as Cd, Cr, Cu, Ni, Pb and Zn in the wastewater effluent might cause the environmental and health risks if not appropriately treated [1-3]. Wastewater might be treated with physical, chemical and biological processes [4-6] to remove the pollutants such as COD, SS, and heavy metals. Generally, the process for wastewater treatment includes primary sedimentation, active sludge process, secondary sedimentation, coagulation, flocculation, filtration, adsorption and chlorination etc. Among them, adsorption [4] is mostly used as final process to remove the trace organic matters and heavy metals. Organic pollutants and metals adsorption were investigated by batch and fixed bed column to understand the removal of contaminants. Biosorbent was used to examine the adsorption capacity with continuous fixed bed column [7]. Akhigbe et al. (2016) investigated the disinfection and removal performance for Escherichia coli and heavy metals by silver-modified zeolite in a fixed bed column [8]. Coalesced chitosan activated carbon composite for batch and fixed-bed adsorption of cationic and anionic dyes was also represented by Auta and Hameed [9]. Evaluation of the adsorptive capacity by peanut hull pellets for heavy metals in solution was also reported [10]. Adsorption and detection of organic pollutants by fixed bed carbon using nanotube electrochemical membrane was examined by Buffa and Mandler [11]. A review of adsorption of heavy metals on conventional and nanostructured materials for wastewater treatment purposes was intensively reported by Burakov et al. [4]. Biosorption of Zn(II) from industrial effluents using sugar beet pulp and F. vesiculosus with laboratory and pilot approach was studied by Castro et al. [12]. Chao et al. [13] reported the biosorption of heavy metals on citrus maxima peel, passion fruit shell, and sugarcane bagasse for copper(II), cadmium(II), nickel(II), and lead(II) metal ion removal in a fixed-bed column. Chatterjee et al. [14] reported adsorptive removal of potentially toxic metals (cadmium, copper, nickel and zinc) by chemically treated laterite: Single and multicomponent batch and column study. Ding et al. [15] investigated the removal of lead, copper, cadmium, zinc, and nickel from aqueous solutions by alkali-modified biochar: Batch and column tests. Ghasemabadi et al. [16] presented the continuous adsorption of Pb(II), As(III), Cd(II), and Cr(VI) using a mixture of magnetic graphite oxide and sand as a medium in a fixed-bed column. Kavand et al. [17] reported the adsorption of heavy metal ions including lead (Pb^{2+}), Cadmium (Cd^{2+}) and Nickel (Ni^{2+}) onto a commercial activated carbon (AC) in single and multi-component aqueous fixed bed column. Different adsorbents for different metals and organic pollutants were investigated as mentioned in the above literature.

This study aims to investigate the breakthrough curve of Cu adsorption by activated carbon via three different influent concentrations using three models (Adams-

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Bohart model, Thmoas model and The Yoon-Nelson model).

2 Materials and methods

The working fixed bed column was 25 cm high and the diameter was 2 cm wide. Thus, the bed volume (BV) was 78.54 cm^3. Activated carbon was used as adsorbent. Three influent Cu concentrations of 1, 10, and 100 mg/L were used as adsorbate. Influent velocity was 25 cm/min. The adsorption experiment was conducted in room temperature about 25 ℃. Characteristics of activated carbon can be seen in Table 1.

The filtrate was collected at each BV such as 1, 2, 3 etc. till the effluent Cu concentrations (C_t) was equal to the influent Cu concentrations (C_0). Plot the BV against the C_t/C_o ratio, the breakthrough curve can be obtained.

Three dynamic adsorption models were used to describe the adsorption behaviour of Cu adsorption on activate carbon. Three dynamic adsorption models (8, 16) were expressed as following three equations:

Adams-Bohart model:

$$\ln(C_t/C_0) = K_{AB}C_0t - K_{AB}N_0(Z/F) \quad (1)$$

where K_{AB} = adsorbed dynamic constant (L/mg-min)
C_t/C_0 = Effluent concentration/Influent concentration
N_0 = Saturated concentration (mg/L)
Z = Height of fixed bed column (cm)
F = Flow velocity of adsorbate (cm/min)

Thomas model:

$$\ln((C_0/C_t)-1) = K_{TH}q_0W/Q - K_{TH}C_0t \quad (2)$$

where K_{TH} = adsorbed dynamic constant (L/mg-min)
C_0/C_t = Influent concentration/Effluent concentration
W = weight of adsorbent (g)
q_0 = adsorbate adsorbed by adsorbent (mg/g)
Q = Influent flow rate (L/min)

$$\ln(C_t/(C_0 - C_t)) = K_{YN}t- \tau K_{YN} \quad (3)$$

where K_{YN} = adsorbed dynamic constant (1/min)
τ = time as 50% adsorbate Cu adsorbed on activated carbon (t)

Table 1. Characteristics of activated carbon.

Parameters	
Particle size	3~4 mm^3
Ball-pan Hardness	≧ 95%
Moisture as packed	≧ 8%
Ash	≧ 5%
Iodine Number	≧ 1050 mg/g
Total Surface Area(BET, N_2)	≧ 1100 m^2/g
Bulk density	0.4~0.55 g/cc
pH of Water Extract	7-11

Using equation (1) ~ (3), plot the Y axis against the X axis (BV), the regression lines were obtained. The parameters in the equations can be obtained as shown in Table 2-4.

3 Results and discussion

Parameters of three models can be found in Table 2-4.

Table 2. Adams–Bohart model-Cu.

Influent conc. (mg/L)	Bed height (mm)	Velocity (mL/min)	K_{AB} (L/mg-min)	N_0 (mg/L)	R^2
1	250	25	0.0296	76.85	0.8579
10	250	25	0.0070	292.84	0.8744
100	250	25	0.0003	2715.92	0.9182

Table 2 showed the parameters of Adams-Bohart model. K_{AB} decreased from 0.0296 to 0.003 L/mg-min as influent concentration increased from 1 to 100 mg/L while N_0 increased from 76.85 to 2715.92 mg/L as influent Cu concentration increased from 1 to 100 mg/L. R^2 was found between 0.8579 and 0.9182.

Table 3. Thomas model-Cu.

Influent conc. (mg/L)	Bed height (mm)	Velocity (mL/min)	K_{TH} (L/min-mg)	q_0 (mg/g)	R^2
1	250	25	0.0442	92.46	0.9065
10	250	25	0.0190	271.34	0.9836
100	250	25	0.0019	1432.41	0.9361

Table 3 showed the parameters of Thomas model. K_{TH} and q_0 showed the similar trend as K_{AB} and N_0 in the Adams-Bohart model. K_{TH} decreased from 0.0442 to 0.0019 L/min-mg as influent Cu concentration increased from 1 to 100 mg/L. q_0 increased from 92.46 to 1432.41 mg/g as influent Cu concentration increased from 1 to 100 mg/L. R^2 of regression model was found between 0.9065 and 0.9836.

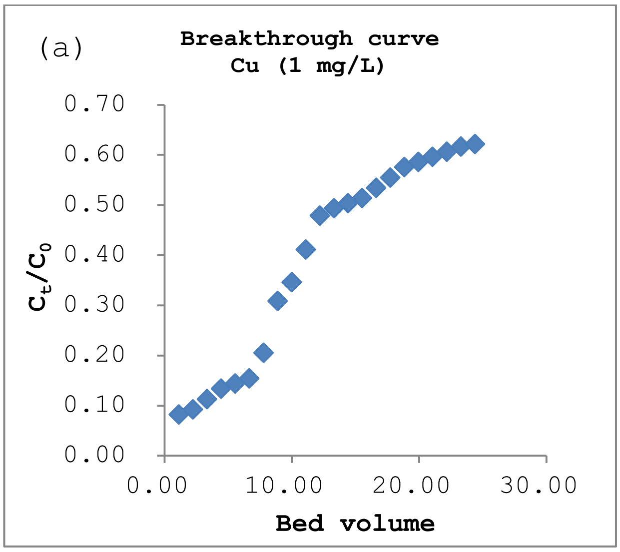
Table 4. The Yoon–Nelson model-Cu.

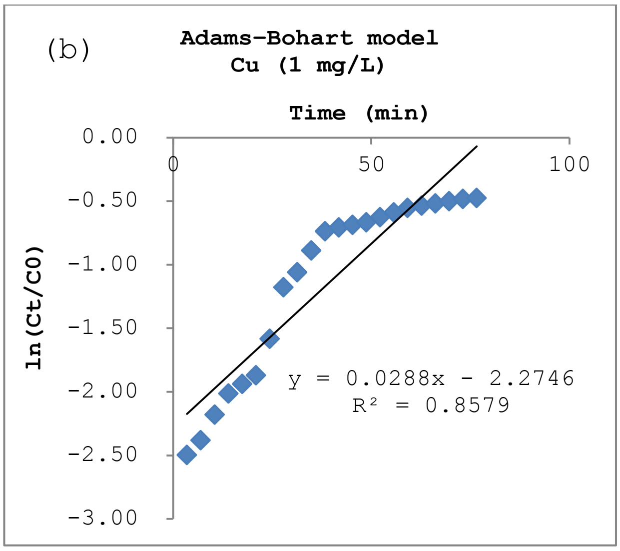
Influent conc. (mg/L)	Bed height (mm)	Velocity (mL/min)	K_{YN} (1/min)	τ (min)	R^2
1	250	25	0.043	53.23	0.9065
10	250	25	0.1898	15.25	0.9836
100	250	25	0.1889	8.05	0.9361

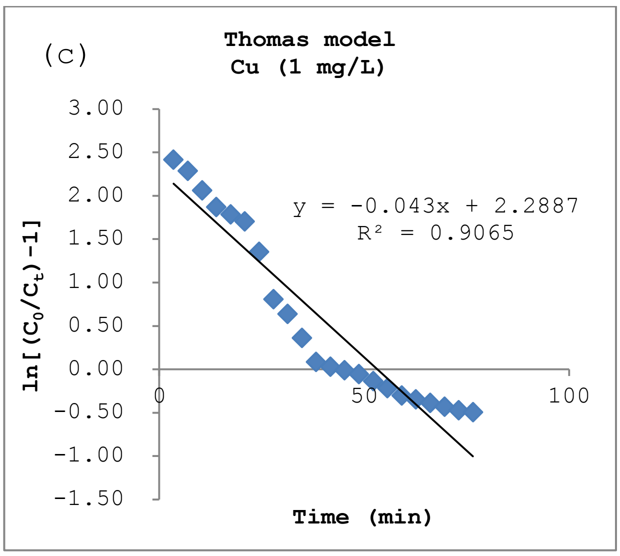
Table 4 showed the parameters of the Yoon-Nelson model. K_{YN} increased as influent Cu concentration increased while τ decreased as influent Cu concentration increased. K_{YN} increased from 0.043 to 0.1889 1/min as influent Cu concentration increased from 1 to 100 mg/L while τ decreased from 53.23 to 8.05 min as influent Cu concentration increased from 1 to 100 mg/L. The τ (53.23 min) needed to be half saturated in the influent Cu concentration of 1 mg/L was ~3.5 times that of 10 mg/L influent Cu concentration and ~7 times that of 100 mg/L influent Cu concentration.

The breakthrough curves of 1, 10 and 100 mg/L Cu influent concentration and the regression of the Adams-Bohart model, Thomas model and The Yoon–Nelson model was shown in Figure 1-3.

Figure 1 showed the influent Cu 1 mg/L adsorption breakthrough curve and the three dynamic adsorption model and regression line. Results was presented in Table 2-4.







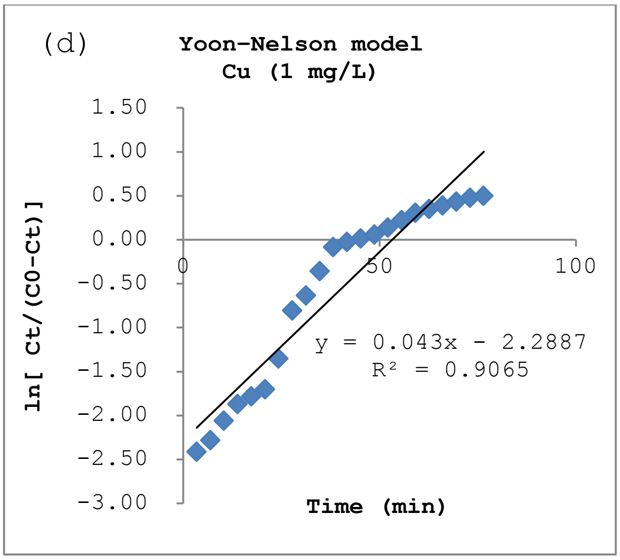
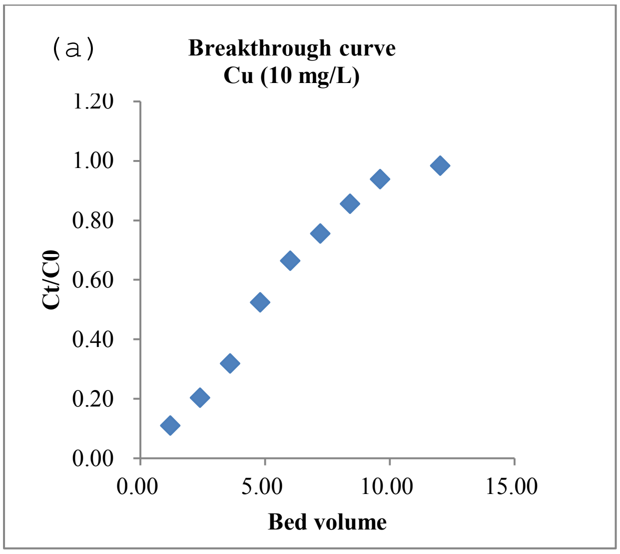
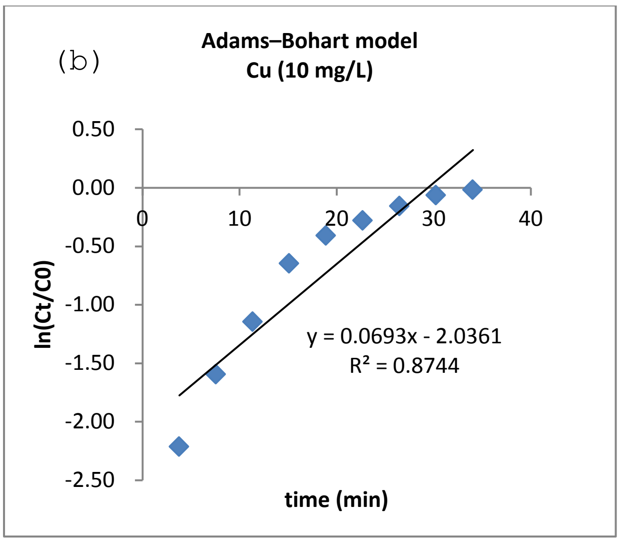


Fig. 1. Cu adsorption breakthrough curve and three dynamic adsorption model in fixed bed column (Cu: ~1 mg/L, column height: 25 cm, flowing velocity: 25 cm/min)

Figure 2 showed the influent Cu 10 mg/L adsorption breakthrough curve and the three dynamic adsorption model and regression line. Results was presented in Table 2-4.





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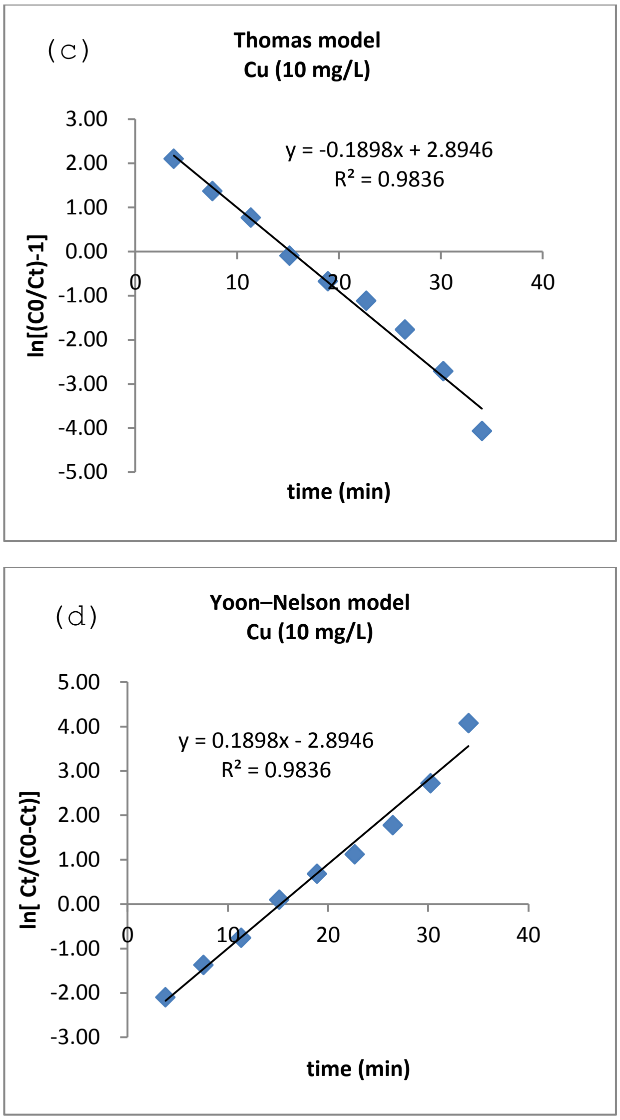
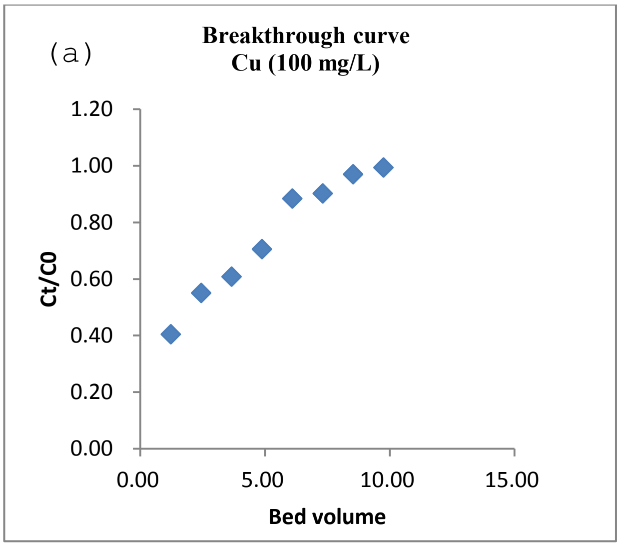


Fig. 2. Cu adsorption breakthrough curve and three dynamic adsorption model in fixed bed column (Cu: ~10 mg/L, column height: 25 cm, flowing velocity: 25 cm/min)

Figure 3 showed the influent Cu 100 mg/L adsorption breakthrough curve and the three dynamic adsorption model and regression line. Results was presented in Table 2-4.



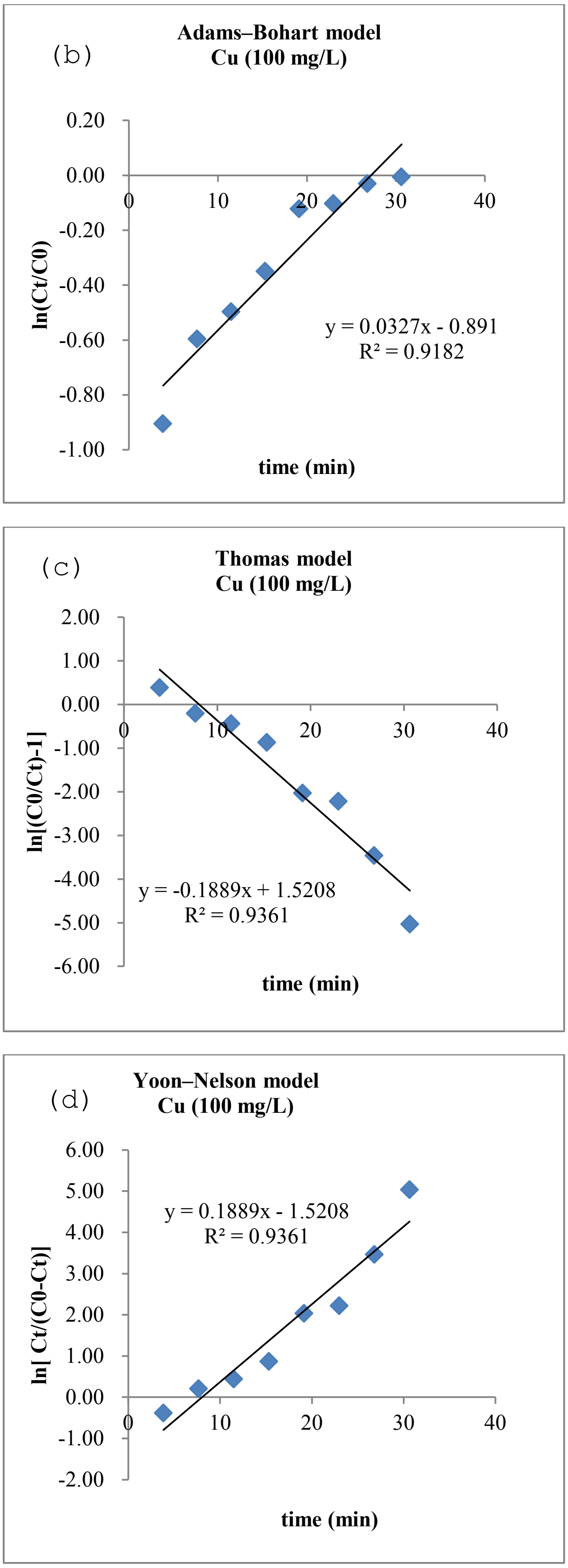


Fig. 3. Cu adsorption breakthrough curve and three dynamic adsorption model in fixed bed column (Cu: ~100 mg/L, column height: 25 cm, flowing velocity: 25 cm/min)

Results showed that Cu adsorption in fixed bed column were described well in the Adams-Bohart model, Thmoas model and The Yoon-Nelson model.

4 Conclusions

Activated carbon was used to adsorb the influent Cu concentration of 1, 10 and 100 mg/L in fixed bed column. Results showed that breakthrough curve was found quick to reach saturation point in influent Cu 100 mg/L concentration than in influent Cu 1 and 10 mg/L concentration. Results also showed that the three models of Adams-Bohart model, Thmoas model and The Yoon-Nelson model were suitable for the description of Cu adsorption.

References

1. B. Hu, S. Shao, Z. Fu, Y. Li, H. Ni, S. Chen, Y. Zhou, B. Jin, Z. Shi, Sci. Total Environ. 658, 614-625 (2019)
2. Q. Yang, Z. Li, X. Lu, Q. Duan, L. Huang, and J. Bi, Sci. Total Environ. 642, 690-700 (2018)
3. L. Zhang, G. Zhu, X. Ge, G. Xu, and Y. Guan, J. Hazard. Mater. **360**, 32-42 (2018)
4. A.E. Burakov, E.V. Galunin, I.V. Burakova, A.E. Kucherova, S. Agarwal, A.G. Tkachev, V.K. Gupta, Ecotoxicol. Environ. Saf. **148**, 702-712 (2018)
5. D. Wang, G. Tang, Z. Yang, X. Li, G. Chai, T. Liu, X. Cao, B. Pan, J. Li, G. Sheng, X. Zheng, Z. Ren, J. Hazard. Mater. (2019), https://doi.org/10.1016/j.jhazmat.2019.03.069
6. L. Wang, Y. Wang, F. Ma, V. Tankpa, S. Bai, X. Guo, X. Wang, Sci. Total Environ. **668**, 1298-1309 (2019)
7. A. Abdolali, H.H. Ngo, W. Guo, J.I. Zhou, J. Zhang, S. Liang, S.W. Chang, D.D. Nguyen, Y. Liu, Bioresour. Technol. **229**, 78-87 (2017)
8. L. Akhigbe, S. Ouki, and D. Saroj, Chem. Eng. J. **295**, 92-98, (2016)
9. M. Auta and B. H. Hameed, Colloids Surf B Biointerfaces **105**, 199-206, (2013)
10. P. Brown, I. Atly Jefcoat, D. Parrish, S. Gill, and E. Graham, Adv. Environ. Res. **4**, 19-29 (2000)
11. A. Buffa and D. Mandler, Chem. Eng. J. **359**, 130-137 (2019)
12. L. Castro, M. L. Blázquez, F. González, J. A. Muñoz, and A. Ballester, Sci. Total Environ. **598**, 856-866 (2017)
13. H.-P. Chao, C.-C. Chang, and A. Nieva, J. Ind. Eng. Chem. . **20**, 3408-3414, (2014)
14. S. Chatterjee, I. Sivareddy, and S. De, J. Environ. Chem. Eng. 5, 3273-3289 (2017)
15. Z. Ding, X. Hu, Y. Wan, S. Wang, and B. Gao, J. Ind. Eng. Chem. **33**, 239-245 (2016)
16. S. M. Ghasemabadi, M. Baghdadi, E. Safari, and F. Ghazban, J. Environ. Chem. Eng. **6**, 4840-4849 (2018)
17. M. Kavand, E. Fakoor, S. Mahzoon, and M. Soleimani, Process Saf. Environ. Prot. **113**, 330-342 (2018)