

(II) (II)

knadafi@sina.tums.ac.ir

// : // :

(II) (II)

(II) (II)

(II) (II)

/ (II) (II)

(II) (II)

(II)

(II)

($R^2 > /$)

%

(II)

(II)

($R^2 > /$)

(II)

(II)

(II) (q_m)

($R^2 > /$)

/ /

(II)

(II) (II)

(II) (II)

Aksu)

(2002; Eckenfelder 2000

(II)

(II)

(Sternberg and Dorn 2002; Volesky 2001)

CaCl₂.2H₂O MgCl₂.6H₂O
 pH . (Merck
 pH /
) /
 (Mixed cellulose ester) / μm CAMLAB) pH (Merck
 ((II) (II)) (Ltd, Model CG842
 :
 FAAS, Chem. Tech Analytical, Model)
 (ALPHA4 AZTEC ENVIRONMENTAL)
 “Standard Methods for B (CONTROL Ltd
 the Examination of Water and Wastewater”
 .(APAH, AWWA and WEF 1998)
 :
 (II) (II) (±)
 :
 () () (Langergren) (II) (II)
 () () (Mixed-order)
 : (/

$$\ln \frac{(q_e - q)}{q_e} = -k_1 t$$
 ()

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t$$
 () / / /

$$\frac{1}{t} \ln \frac{C_0}{C_t} = -\frac{k_0}{K} - \frac{1}{K} \left(\frac{C_0 - C_t}{t} \right)$$
 () pH . /

$$\frac{1}{(q_e - q_t)} = \frac{1}{q_e} + kt$$
 ()
 :q_e q () :t
)
) :k₁ (
) :k₂ (
 :C_t C₀ (
 () k₀ () t
 :k : () K (II)
 () (II)
 Azizian 2004; Benguella and)
 .(Benaissa 2002; Metcalf and Eddy Inc 2003
 pH . / (II) (II)

$$n \quad q_m \quad b \quad : \quad (II) \quad (II)$$

(Volesky 2003)

$$q_e = \frac{K_{RP} C_e}{1 + a_{RP} C_e^\beta} \quad ()$$

$a_{RP} () K_{RP}$
 $() \beta (\beta)$
 (Aksu 2002; Volesky 2003)

$$(II) \quad (II) \quad :$$

$$(II) \quad (II)$$

$$q_e = \frac{b q_m C_e}{1 + b C_e} \quad ()$$

C_e
 $q_m ()$
 $b ()$
 Sheng et al. 2004; Yalçınkaya et al.)

(2002

$$(II) \quad (II)$$

$$(II) \quad (II)$$

$$q_e = K_F C_e^{1/n} \quad ()$$

$n \quad K_F$

$$(II) \quad (q_m) \quad (II)$$

Loukidou et al.)
 (. 2004, Selatnia et al. 2004b

$$(II) \quad (II)$$

$$q_e = \frac{b q_m C_e^{1/n}}{1 + b C_e^{1/n}} \quad ()$$

% %

(Yan and Viraraghavan 2003)

(k₂)

/ : (II)

/ / /

(k₀)

/ : (II)

/ / /

(*Ascophyllum nodosum*)

Kuyucak)

(; and Volesky 1989

(II)

(k₂)

(II)

/ /

/

/

% %

(II)

(k₀)

/

/

(III)

/ /

%

(II)

(II)

(II)

(II)

(II)

(II)

Matheickal and)

%

(II)

(Yu 1999

(II)

pH

(R² > /)

(II)

(II)

(II)

(II)

(II)

pH (II)

pH

(II)

pH

pH

/ / /

/

Aeromonas)

(VI)

/ (II)

(*caviae*)

/ / /

pH

(II)

(II)

(II)

Mucor)

(II)

(*rouxii*)

Diniz and) .

(II) (II) (III) (III) (III) (Volesky 2005

() (II) (Oscillatoria anguistissima) (Ahuja et al. 1999)

(II) pH (II) Aksu) (II) (II) (2002) (R²> /)

(II) (II) (q_m) (R²> /) / /

(II) (II)

(II)

(II)

: (II) (II) (q_m) / / (q_m)

(Volesky 2001)

(... pH)

/ ... (II) (II)

Cd ²⁺			Pb ²⁺			Saturation						(Mm)	
R ²	k (gmmol ⁻¹ min ⁻¹)	q _e (mmolg ⁻¹)	R ²	k ₀ (mMmin ⁻¹)	K (Mm)	R ²	k ₂ (gmmol ⁻¹ min ⁻¹)	q _e (mmolg ⁻¹)	R ^{2*}	k ₁ (min ⁻¹)	q _e (mmolg ⁻¹)		
/	/	/	/	/	/	/	/	/	/	/	/		Pb ²⁺
/	/	/	/	/	/	/	/	/	/	/	/		Pb ²⁺
/	/	/	/	/	/	/	/	/	/	/	/	/	Pb ²⁺
/	/	/	/	/	/	/	/	/	/	/	/		Cd ²⁺
/	/	/	/	/	/	/	/	/	/	/	/		Cd ²⁺
/	/	/	/	/	/	/	/	/	/	/	/	/	Cd ²⁺

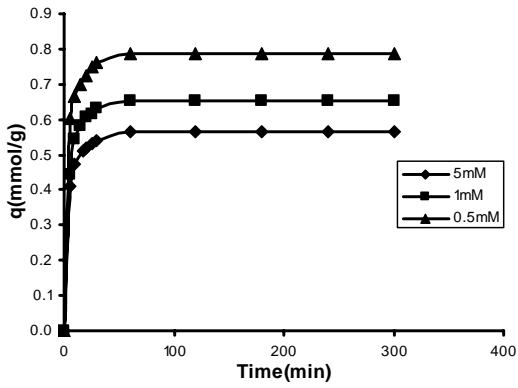
:R*

(II) (II)

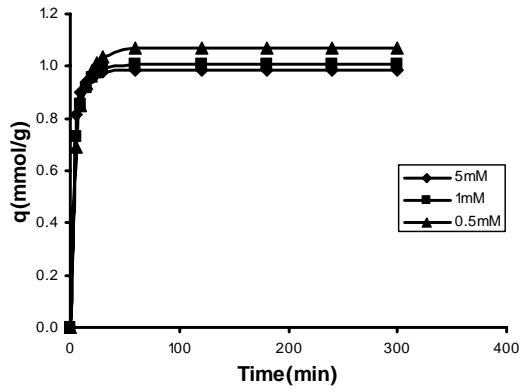
R ²	n	K _F	R ^{2*}	b(Lmmol ⁻¹)	q _m (mmolg ⁻¹)	
/	/	/	/	/	/	(II)
/	/	/	/	/	/	(II)

:R*

(II)		(II)		-					
R ²	β	K _{RP} (Lg ⁻¹)	a _{RP} (Lmmol ⁻¹) ^β	R ^{2*}	n	b	q _m		
/	/	/	/	/	/	/	/	(II)	
/	/	/	/	/	/	/	/	(II)	
:R*									
		(°C)	pH	(II)		(II)		(q _m)	
		(°C)	pH	q _m (mmolg ⁻¹)					
Matheickal and Yu 1996			/ /	/			Ecklonia)		
Sheng et al. 2004	±			/			(radiata	Pb ²⁺	
Sheng et al. 2004	±			/			(Ulva sp.)		
Sheng et al. 2004	±			/			(Padina sp.)		
Jalali et al. 2002			/	/			(Gracillaria sp.)		
Say et al. 2001				/			(Cladophora glomerata)		
Yan and Viraraghavan 2003				/			(Phanerochaete)		
Selatnia et al. 2004b				/			(chryso sporium		
Xiangliang et al. 2005			/	/			Mucor)		
Suzuki et al. 2005			/	/			(rouxii		
Sheng et al. 2004	±		/	/			(Streptomyces rimosus)		
Sheng et al. 2004	±		/	/			(Pleurotus ostreatus)		
Sheng et al. 2004	±		/	/			(Ulva onoi)	Cd ²⁺	
Yan and Viraraghavan 2003				/			(Ulva sp.)		
Say et al. 2001				/			(Padina sp.)		
Yalçınkaya et al. 2002				/			(Gracillaria sp.)		
Selatnia et al. 2004a				/			Mucor)		
Benguella and Benaissa 2002			/ /	/			(rouxii		
				/			(Phanerochaete)		
				/			(chryso sporium		
				/			(Trametes versicolor)		
				/			(Streptomyces rimosus)		
				/			(Chitin)		



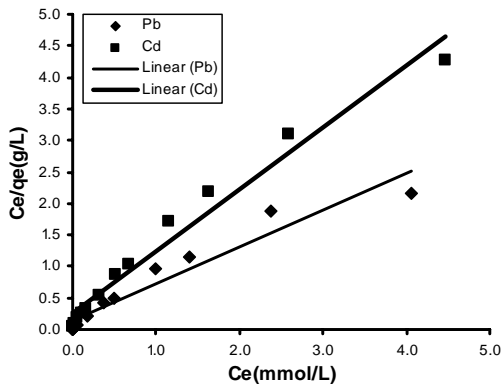
()



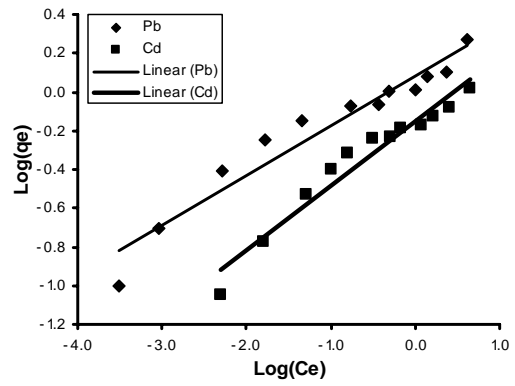
()

() (II)

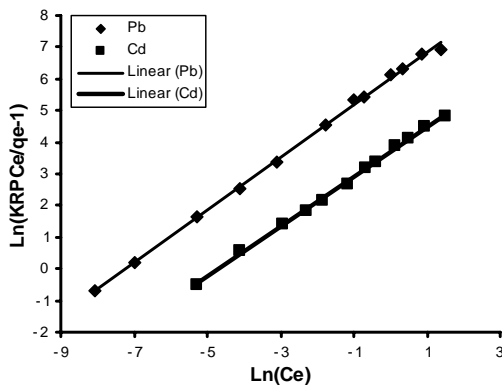
() (II)



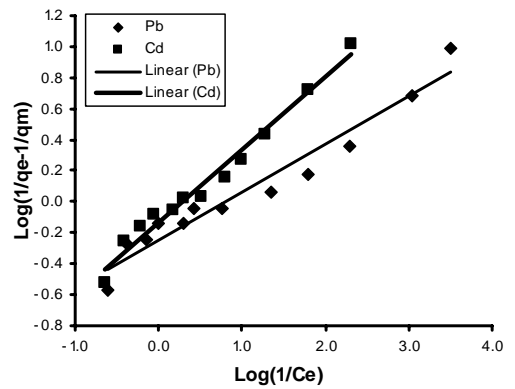
()



()



()



()

(II)

(II)

()

()

()

()

References

- Ahuja, P., Gupta, R. and Saxena, R.K., 1999. Zn²⁺ biosorption by *Oscillatoria anguistissima*. *Process. Biochem.* **34**, pp.77-85.
- Aksu, Z., 2002. Determination of the equilibrium, kinetic and thermodynamic parameters of the batch biosorption of nickel(II) ions onto *Chlorella vulgaris*. *Process. Biochem.* **38**, pp.89-99.
- APAH, AWWA and WEF, 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th ed. United Book Press, Baltimore, Maryland.
- Azizian, S., 2004. Kinetic models of sorption: a theoretical analysis. *J. Coll. Interf. Sci.* **276**, pp.47-52.
- Benguella, B. and Benaissa, H., 2002. Cadmium removal from aqueous solutions by chitin: kinetic and equilibrium studies. *Water Res.* **36**, pp.2463-2474.
- Cossich, E.S., Tavares, C.R.G. and Ravagnani, T.M.K., 2002. Biosorption of chromium(III) by *Sargassum* sp. Biomass. *Electronic Journal of Biotechnol.* **5**(2), pp.133-140.
- Davis, T.A., Volesky, B. and Mucci, A., 2003. A review of the biochemistry of heavy metal biosorption by brown algae. *Water Res.* **37**(18), pp.4311-4330.
- Diniz, V. and Volesky, B., 2005. Biosorption of La, Eu and Yb using *Sargassum* biomass. *Water Res.* **39**, pp.239-247.
- Eckenfelder, W.W., Jr., 2000. *Industrial Water Pollution Control*. 3rd ed. McGraw-Hill Inc., Boston, MA, pp.138-142.
- Jalali, R., Ghafourian, H., Asef, Y., Davarpanah, S.J. and Sepehr, S., 2002. Removal and recovery of lead using nonliving biomass of marine algae. *J. Hazard. Mater.* **B92**, pp.253-262.
- Kiff, R.J. and Little, D.R., 1986. Biosorption of heavy metals by immobilized fungal biomass. In: Hunt E.H., ed, *Immobilization of Ions by Biosorption*. Ellis Horwood, Chichester, UK. p.219.
- Kuyucak, N. and Volesky, B., 1989. Accumulation of cobalt by marine algae. *Biotechnol. Bioeng.* **33**, pp.809-814.
- Loukidou, M.X., Matis, K.A., Zouboulis, A.I. and Kyriakidou, M.L., 2003. Removal of As(V) from wastewaters by chemically modified fungal biomass. *Water Res.* **37**, pp.4544-4552.
- Loukidou, M.X., Zouboulis, A.I., Karapantsios, T.D. and Matis, K.A., 2004. Equilibrium and kinetic modeling of chromium(VI) biosorption by *Aeromonas caviae*. *Colloids Surf. A: Physicochem. Eng. Aspects.* **242**, pp.93-104.
- 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. *Biores. Technol.* **69**(3), pp.223-229.
- Matheickal, J.T. and Yu, Q., 1996. Biosorption of lead from aqueous solutions by marine algae *Ecklonia adiate*. *Water Sci. Technol.* **34**(9), 1-7.
- Metcalf and Eddy Inc., 2003. *Wastewater Engineering: Treatment and Reuse*. 4th ed. McGraw-Hill Inc., New York. pp.260-265.
- Say, R., Denizli, A. and Arica, M.Y., 2001. Biosorption of cadmium(II), lead(II) and copper(II) with the filamentous fungus *Phanerochaete chrysosporium*. *Biores. Technol.* **76**, pp.67-70.
- Selatnia, A., Bakhti, M.Z., Madani, A., Kertous, L. and Mansouri, Y., 2004a. Biosorption of Cd²⁺ from aqueous solution by a NaOH-treated bacterial dead *Streptomyces rimosus* biomass. *Hydrometallurgy.* **75**, pp.11-24.
- Selatnia, A., Boukazoula, A., Kechid, N., Bakhti, M.Z., Chergui, A. and Kerchich, Y., 2004b. Biosorption of lead(II) from aqueous solution by a bacterial dead *Streptomyces rimosus* biomass. *Biochem. Eng. J.* **19**, pp.127-135.
- Sheng, P.X., Ting, Y.P., Chen, J.P. and Hong, L., 2004. Sorption of lead, copper,

- cadmium, zinc and nickel by marine algal biomass: characterization of biosorptive capacity and investigation of mechanisms. *J. Coll. Interf. Sci.* **275**, pp.131-141.
- Sternberg, S.P.K. and Dorn, R.W., 2002. Cadmium removal using *Cladophora* in batch, semi-batch and flow reactors. *Biores. Technol.* **81**, pp.249-255.
- Suzuki, Y., Kametani, T. and Maruyama, T., 2005. Removal of heavy metals from aqueous solution by nonliving *Ulva* seaweed as biosorbent. *Water Res.* **39**, pp.1803-1808.
- Volesky, B., 2001. Detoxification of metal-bearing effluents: biosorption for the next century. *Hydrometallurgy.* **59**, pp.203-216.
- Volesky, B., 2003. Biosorption process simulation tools. *Hydrometallurgy.* **71**, pp.179-190.
- Xiangliang, P., Jianlong, W. and Daoyong, Z., 2005. Biosorption of Pb(II) by *Pleurotus ostreatus* immobilized in calcium alginate gel. *Process. Biochem.* **40**, pp.2799-2803.
- Yalçinkaya, Y., Soysal, L., Denizli, A., Arica, M.Y., Bektaş, S. and Genç, Ö., 2002. Biosorption of cadmium from aquatic systems by carboxymethylcellulose and immobilized *Trametes versicolor*. *Hydrometallurgy.* **63**, pp.31-40.
- Yan, G. and Viraraghavan, T., 2003. Heavy metal removal from aqueous solution by fungus *Mucor rouxii*. *Water Res.* **37**, pp.4486-4496.
- Zhang, L., Zhao, L., Yu, Y. and Chen, C., 1998. Removal of lead from aqueous solution by non-living *Rhizopus nigricans*. *Water Res.* **32**, pp.1437-1444.