

Patcharin Racho; Weesuda Waiwong

Article

Modified textile waste for heavy metals removal

Energy Reports

Provided in Cooperation with:

Elsevier

Suggested Citation: Patcharin Racho; Weesuda Waiwong (2020) : Modified textile waste for heavy metals removal, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 1, pp. 927-932, <https://doi.org/10.1016/j.egy.2019.12.017>

This Version is available at:

<https://hdl.handle.net/10419/243844>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>

6th International Conference on Energy and Environment Research, ICEER 2019, 22–25 July,
University of Aveiro, Portugal

Modified textile waste for heavy metals removal

Patcharin Racho*, Weesuda Waiwong

Suranaree University of Technology, Nakhon Ratchasima 30000, Thailand

Received 19 December 2019; accepted 19 December 2019

Available online 9 January 2020

Abstract

The performance of chemically modified textile waste for a heavy metal treatment is reported in this study. Two sorbents, which were prepared by a simple and concise method, were able to bind two heavy metals including Pb(II) and Cr(VI), with very high efficiencies. The binding mechanisms were studied through adsorption tests such as the influence of contact times, heavy metal concentrations as well as elution study. The overall results showed that the adsorption kinetics was very fast and attained an equilibrium within 180 min in all metals studied. The maximum single metal uptakes were 11.81 mg/g and 1.97 mg/g, for Pb(II) and Cr(VI), respectively. The sorbent could potentially be effective in treating large volumes of wastewater.

© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of the 6th International Conference on Energy and Environment Research, ICEER 2019.

Keywords: Modified textile; Textile waste; Chemisorption; Graft copolymerization; Amino chelating; Ion exchange

1. Introduction

Due to the high toxicity associated with heavy metals, their continuous output by industries and their presence in our surrounding water bodies pose environmental threats that need to be addressed urgently. The most commonly found heavy metals are chromium (Cr(VI)) and lead (Pb(II)), which when present in high concentrations may be very fatal to human health and the surrounding environment as well [1]. Several methods are available for the treatment and removal of heavy metals. Currently, adsorption has become the focus of attention for the removal of heavy metal ions from water and wastewater. This focus is due to the regeneration of adsorbent, the minimization of chemical and or biological sludge, its high efficiency, the possibility of metal recovery, its flexibility and the simplicity of the design [2]. New types of adsorbents arose in recent years based on chemically modified textiles because it has a high adsorption capacity, a fast adsorption equilibrium and easy regeneration.

One adsorption technique is through the chemical modification of cellulose whose high-affinity functional groups including sulfur-bearing groups that can be introduced for metal binding. Sulfur-bearing groups in particular have higher affinities for heavy metals and low affinities for light metals. Different sulfur-bearing compounds include thiols, dithiocarbamates, dithiophosphates and xanthates. Of these, xanthates are the most well-known and are

* Corresponding author.

E-mail address: patcha@sut.ac.th (P. Racho).

<https://doi.org/10.1016/j.egy.2019.12.017>

2352-4847/© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of the 6th International Conference on Energy and Environment Research, ICEER 2019.

widely used owing to their easy preparation from inexpensive reagents, their high insolubility, and their ability to form stable xanthate metal complexes with heavy metal ions. They are predominantly used in the mining industry as flotation agents to separate hydrophobic materials from hydrophilic ones. Xanthates function similarly to the much-used hydroxide precipitation method. However, unlike precipitation, the sludge formed from xanthate metal complexes can easily settle, can be dewatered and disposed of, and have very promising removal efficiency and kinetics. Furthermore, metal hydroxide precipitates may release metals into the environment during disposal, and thus further treatments such as solidification/stabilization should be required [3].

The amount of textile waste has been increasing rapidly in recent years. The increasing world population inevitably leads to outstripping demand in consumer products such as textiles and apparel. These textile wastes give rise to many disposal problems and governance issues, and should be recycled in order to achieve sustainable development. Therefore, this study aims to investigate the effect of chemical modification of textile waste by amino bearing. Heavy metal removal was evaluated through several factors including the influence of contact time, the initial metal concentration, the adsorption kinetics, adsorption isotherms as well as the study of elution.

2. Materials and methods

2.1. Adsorbent preparation

Two sources of textile waste, household and industrial, were prepared by chemical modification processes. The two textile wastes were washed with acetone, and dried at 40 °C in a hot air oven before chemical modification. The chemical modification process was carried out with the following two steps [4]:

- The graft copolymerization of textiles by poly-acrylic acid (PAA) was carried out using free radical polymerization. Briefly, 5.000 g of pre-treated textile was soaked in 250 ml distilled water in a conical flask. Then, the redox initiator system [Benzoyl Peroxide (BPO), toluene, Tween-80] was added and the mixture which was then vigorously shaken for 5 min. The AA monomer was added and the reaction was conducted for 8 h with stirring at 363 K. The products were filtered and washed with distilled water. Then, the grafted copolymer was dried at 313 K until achieving a constant weight.
- The finally chelating textiles were prepared by the action of the above Textile-AA with 1000 mL, 10%(v/v) ethylenediamine solution. The mixture was stirred at 313 K for 8 h. Then, the chelating fibers were filtered and washed with absolute ethanol then dried at 313 K.

2.2. Batch sorption study

The adsorption capacity of the amino chelating textiles for Pb(II) and Cr(VI) ion were investigated by the batch method and a single element system. This study evaluated the influence of contact time and the initial metal concentration. Dried samples of 0.100 g of the chelating textile wastes were added in a 250 mL Erlenmeyer flask including volumes of 100 mL of the metal ion solution. The mixture was stirred at 25 °C. The flask was agitated on a shaker for 4 h. After filtration of the solution using 40 grade filter papers, the ion concentrations of the filtrates were analyzed with an atomic adsorption spectrophotometer (AAS), Perkin Elmer, Model: PinAAcle 900F [4].

2.3. Elution study of ions

The elution of metal ions was studied with HNO₃ in batch experiments. The metal ion loaded textiles were placed in an elution medium and stirred at 25 °C. The final metal ion concentration in the aqueous phase were determined with an AAS [5].

3. Results and discussion

3.1. Effect of contact time on the removal of Pb(II) and Cr(VI)

The effect of contact time on the Pb(II) and Cr(VI) adsorption were evaluated in a range of 10 – 210 min and the initial heavy metal concentration was 50 mg/L.

As shown in Fig. 1. The adsorption capacity increased gradually as the contact time increased up to 180 min, thereafter the equilibrium adsorption capacities were recorded, as in the study by Racho and Phalathip [6] that proposed Pb(II) and Cr(VI) removal by using amino-textiles with equilibrium times of 150 and 180 min, respectively. The maximum adsorption capacity for Pb(II) and Cr(VI) removal for the modified household textile waste was 2.17 and 1.85 mg/g, respectively, and for the modified industry textile waste it was 2.05 and 1.97 mg/g, respectively.

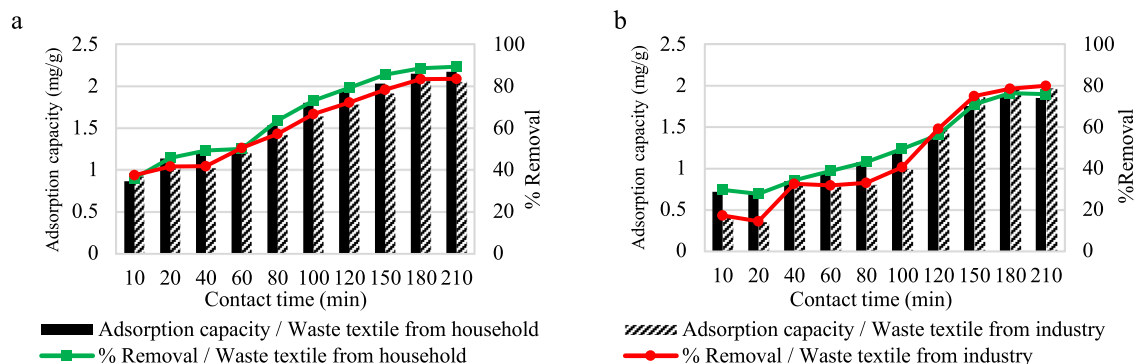


Fig. 1. Effect of contact time on the removal of (a) Pb(II) with initial concentration 50 mg/L and pH 5 and (b) Cr(VI) with initial concentration 50 mg/L and pH 3.

3.2. Effect of initial concentration on the removal of Pb(II) and Cr(VI)

The effect of initial concentration on the Pb(II) and Cr(VI) adsorption were evaluated in a range of 10 – 250 mg/L and the contact time was 180 min.

As shown in Fig. 2. The adsorption capacity increased gradually as the initial concentration increased up to 100 mg/L. Above that, the equilibrium adsorption capacities were obtained, as in the study by Coşkun and Soykan [5] that proposed Pb(II) and Cr(VI) removal by modified textile waste, which become saturated when the metal ion concentration reached 100 mg/L. The maximum adsorption capacity of Pb(II) and Cr(VI) were about 11.81 mg/g and 2.19 mg/g, respectively, on modified textile waste from households and for the modified textile waste from industry the capacities were about 11.58 and 1.63 mg/g for Pb(II) and Cr(VI), respectively.

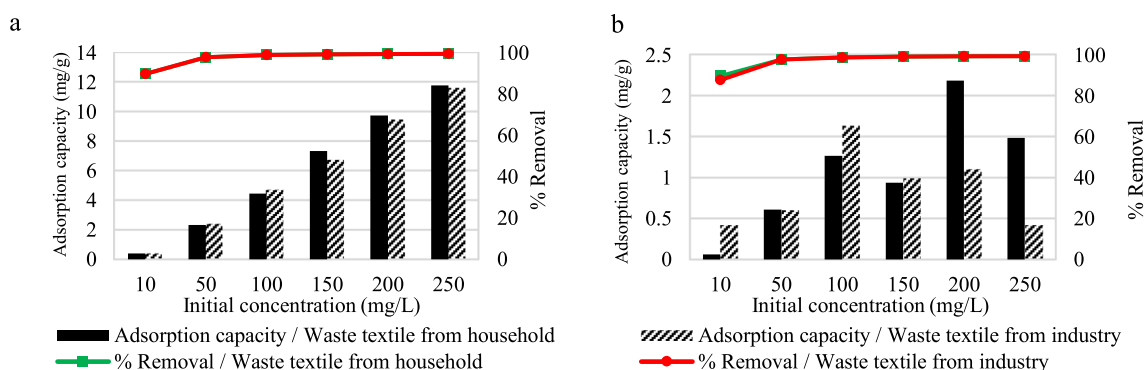


Fig. 2. Effect of initial concentration on the removal of (a) Pb(II) with contact time 180 min and pH 5 and (b) Cr(VI) with contact time 180 min and pH 3.

3.3. Adsorption kinetics

The data for the uptake time was treated in the form of two simplified kinetic models including the pseudo-first-order and pseudo-second-order equations [7,8] and the equations are expressed as:

$$\log(q_e - q_t) = \log q_e - \left(\frac{k_1}{2.303} \right) t \quad (1)$$

$$\frac{t}{q_t} = \frac{t}{q_e} + \frac{1}{k_2 q_e^2} \tag{2}$$

The pseudo first and second order equations are described by Dong et al. [9]. The values of R^2 show that the pseudo second order equation gave a better fit to the sorption process than a pseudo first order model. The smallest values of R^2 were 0.9567 and 0.9906 for Pb(II) and Cr(VI), respectively as shown in Fig. 3 (see Table 1).

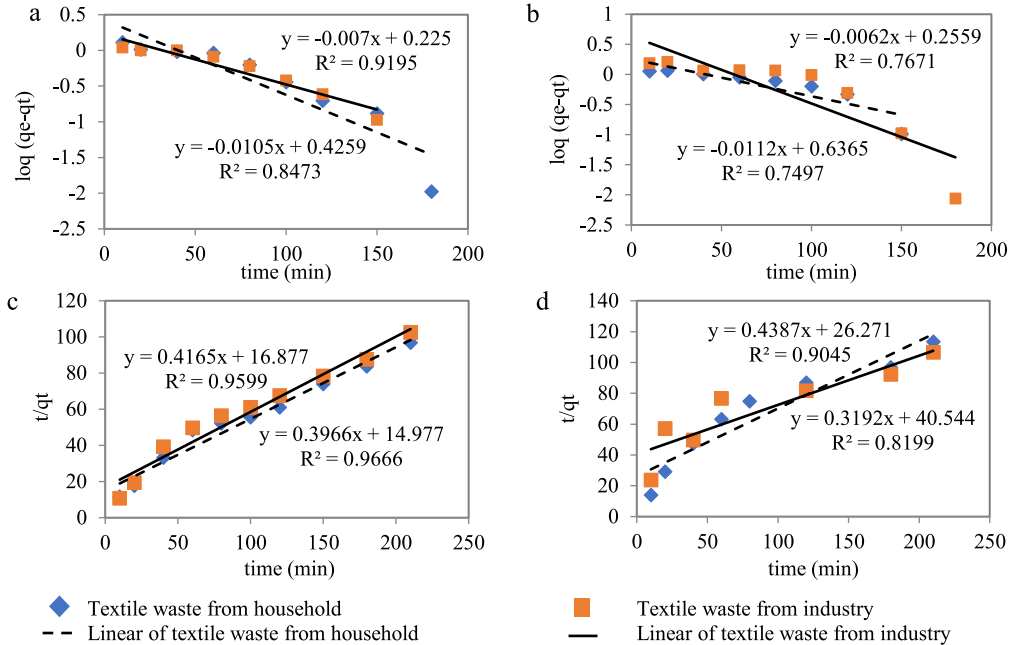


Fig. 3. Pseudo-First-Order Model of (a) Pb(II) and (b) Cr(VI) and Pseudo-Second-Order Model of (c) Pb(II) and (d) Cr(VI).

Table 1. Pseudo first order and Pseudo second order rate constants.

Textile	Heavy metals	Pseudo-first-order model		Pseudo-second-order model	
Textile waste from household	Pb (II)	$q_e(m_{eq}/g)$	2.67	$q_e(m_{eq}/g)$	2.52
		$k_1(min^{-1})$	0.024	$k_2(g/m_{eq}.min)$	0.026
		R^2	0.7497	$h(m_{eq}/g.min)$	0.17
				R^2	0.9666
Textile waste from industry	Cr (VI)	$q_e(m_{eq}/g)$	4.33	$q_e(m_{eq}/g)$	2.28
		$k_1(min^{-1})$	0.026	$k_2(g/m_{eq}.min)$	0.07
		R^2	0.7497	$h(m_{eq}/g.min)$	0.36
				R^2	0.9045
Textile waste from household	Pb (II)	$q_e(m_{eq}/g)$	1.68	$q_e(m_{eq}/g)$	2.40
		$k_1(min^{-1})$	0.161	$k_2(g/m_{eq}.min)$	0.01
		R^2	0.9195	$h(m_{eq}/g.min)$	0.06
				R^2	0.9599
Textile waste from industry	Cr (VI)	$q_e(m_{eq}/g)$	1.80	$q_e(m_{eq}/g)$	3.13
		$k_1(min^{-1})$	0.014	$k_2(g/m_{eq}.min)$	0.01
		R^2	0.7671	$h(m_{eq}/g.min)$	0.12
				R^2	0.8199

The adsorption process is generally known to be controlled by the transport of the species to be adsorbed from the bulk solution to the surface of the adsorbent and then the attachment of the transported species on the surface of the adsorbent. The rapid adsorption equilibrium for both Pb(II) and Cr(VI) is an indication that the surface of the modified textile waste was readily available for adsorption. This is different from the activated carbon mechanism in which many micropores are used. Adsorption takes a very long time to reach adsorption equilibrium or it cannot

be accessed, which is attributed to the slow internal pore diffusion transport effect and is also dependent on the micropore dimensions [10].

3.4. Adsorption isotherms

The equilibrium adsorption isotherms of Pb(II) and Cr(VI) on chelating textiles at 293 K were calculated for the interpretation of the adsorption data, using the Freundlich [11] and Langmuir [12] isotherm models (Eqs. (3) and (4)):

$$\frac{C_e}{q_e} = \frac{1}{q_{\max}K_L} + \frac{C_e}{q_{\max}} \tag{3}$$

$$\log q_e = \frac{1}{n} \log C_e + \log K_F \tag{4}$$

The results suggest that the equilibrium data was described well by the Freundlich isotherm, probably due to the real heterogeneous nature of the surface sites like $-\text{NH}^{3+}$ and $=\text{NH}^{2+}$ involved in the chromium uptake. To a lesser extent, the isotherm also gave an acceptable fit indicating that the hexavalent ions were absorbed from the monolayer coverage on the adsorbent surface. Generally, the application of the Langmuir model seemed to be more appropriate than that of Freundlich model. This interesting Pb(II) and Cr(VI) adsorption behavior was also found on polyaniline that contained abundant amine groups ([9]; Deng et al. 2004) (see Table 2).

Table 2. Freundlich isotherm constant.

Textile	Heavy metals	Freundlich		
		K_f (mg/g) \times (L/g)	n	R ²
Textile waste from household	Pb(II)	0.05	1	0.9999
Textile waste from household	Cr(VI)	0.05	1	0.9999
Textile waste from industry	Pb(II)	0.05	1	0.9997
Textile waste from industry	Cr(VI)	0.05	1	0.9997

3.5. Elution study

An important characteristic of an adsorbent is the possibility for its regeneration for further use. This is why the elution of the metal loaded fibers was studied. The elution was performed with 1M HNO₃, and the elution degrees of heavy metal ions are presented in Fig. 4. As shown in Fig. 4, the elution degree of Pb(II) is higher than for the Cr(VI) metal ions. This may be attributed to the weaker coordination bonds between Pb(II) ions and the adsorbent functional groups. However, the amount of Pb(II) and Cr(VI) adsorbed on the modified textile waste decreased after each adsorption–regeneration cycle, implying that it was not completely desorbed from the surfaces of the modified textile waste for each regeneration process.

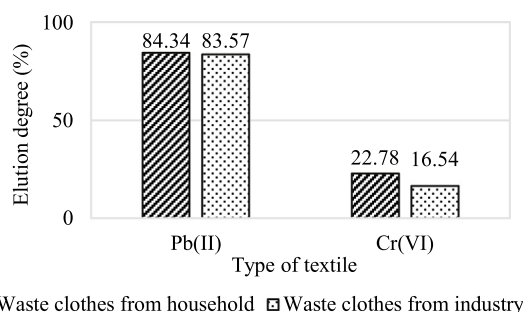


Fig. 4. Elution degree of heavy metal ions; Pb(II) and Cr(VI).

4. Conclusions

The following conclusions could be drawn from this conducted experiment:

- (1) The adsorption capacity increased gradually as the contact time increased up to 180 min, thereafter the equilibrium adsorption capacities were obtained.
- (2) The adsorption capacity increased gradually as the initial concentration increased up to 100 mg/L., thereafter the equilibrium adsorption capacities were obtained.
- (3) The values of R^2 show that the pseudo second order equation gave a better fit to the sorption process than a pseudo first order model.
- (4) The results suggest that the equilibrium data were well described by Freundlich isotherm, probably due to the real heterogeneous nature of the surface sites like $-\text{NH}^{3+}$ and $=\text{NH}^{2+}$ involved in the chromium uptake. Generally, the application of the Langmuir model seemed to be more appropriate than that of Freundlich model. This interesting Pb(II) and Cr(VI) adsorption behavior was also found on polyaniline that contained abundant amine groups.
- (5) The elution degree of Pb(II) is higher than that for the Cr(VI) metal ions. This may be attributed to weaker coordination bonds between Pb(II) ions and the adsorbents' functional groups.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors express their sincere gratitude for the great support for this work by Suranaree University of Technology, Thailand.

References

- [1] King P, Srinivas P, Yekula Prasanna Kumar, Prasad VSRK. Sorption of copper (II) ion from aqueous solution by tectona grandis l.f. (teak leaves powder). *J Hazard Mater* 2006;136.
- [2] Ahalya N, Ramachandra TV, Kanamadi RD. Biosorption of heavy metals. *Res J Chem Environ* 2003;7:71–8.
- [3] Bediako John, Wei Wei, Kim Sok, Yun Yeoung-Sang. Removal of heavy metals from aqueous phases using chemically modified waste Lyocell fiber. *J Hazard Mater* 2015.
- [4] Wang J, Xu L, Cheng C, Meng Y, Li A. Preparation of new chelating fiber with waste PET as adsorbent for fast removal of Cu^{2+} and Ni^{2+} from water: Kinetic and equilibrium adsorption studies. *Chem Eng J* 2012;193–194:31–8.
- [5] Coşkun R, Soykan C. Preparation of amidoximated polyester fiber and competitive adsorption of some heavy metal ions from aqueous solution onto this fiber. *J Appl Polym Sci* 2009.
- [6] Racho P, Phalathip P. Modified nylon fibers with amino chelating groups for heavy metal removal. *Energy Procedia* 2017;118:195–200.
- [7] Hameed BH, Ahmad AA, Aziz N. Isotherms, kinetics and thermodynamics of acid dye adsorption on activated palm ash. *Chem Eng J* 2007;133:195–203.
- [8] Ho YS, Huang CT, Huang HW. Equilibrium sorption isotherm for metal ions on tree fern. *Process Biochem* 2002;37:1421–30.
- [9] Dong A, Xie J, Wang W, Yu L, Liu Q, Yin Y. A novel method for amino starch preparation and its adsorption for Cu(II) and Cr(VI). *J Hard Mater* 2010;181(1–3):448–54.
- [10] Deng S, Bai R. Removal of trivalent and hexavalent chromium with aminated polyacrylonitrile fibers: Performance and mechanisms. *Water Res* 2004;38(9):2424–32.
- [11] Ho YS. Review of second-order models for adsorption systems. *J Hard Mater* 2006;136(3):681–9.
- [12] Deng S, Ting YP. Fungal biomass with grafted poly (acrylic acid) for enhancement of Cu (II) and Cd (II) Biosorption, (Ii). 2005, p. 6032–40.