Routledge
Taylor & Francis Group

International Journal of Environmental Studies

ISSN: 0020-7233 (Print) 1029-0400 (Online) Journal homepage: www.tandfonline.com/journals/genv20

Biosorption of Acid Red P-2BX by lichens as low-cost biosorbents

Gizem Bayazıt, Ülküye Dudu Gül & Dilek Ünal

INTERNATIONAL JOURNAL OF ENVIRONMENTAL STUDIES
2019, VOL. 76, NO. 4, 608–615
https://doi.org/10.1080/00207233.2018.1502959

ARTICLE

Biosorption of Acid Red P-2BX by lichens as low-cost biosorbents

Gizem Bayazıt[a], Ülküye Dudu Gül[b,c] and Dilek Ünal[c,d]

[a]Department of Biotechnology, Bilecik Seyh Edebali University, Bilecik, Turkey; [b]Vocational School of Health Services, Bilecik Seyh Edebali University, Bilecik, Turkey; [c]Biotechnology Research and Application Centre, Bilecik Seyh Edebali University, Bilecik, Turkey; [d]Molecular Biology and Genetics, Bilecik Seyh Edebali University, Bilecik, Turkey

ABSTRACT

The aim of this study is to examine the dye biosorption properties of lichen species called *Cladonia convoluta* and *Evernia prunastri*. Since lichens are extensively found in the environment, their suitability as a cheap adsorbent has been investigated in this study. The optimal parameters for textile dye biosorption were also determined. The dried lichen biomass showed better dye biosorption capacity than ash lichen biomass. *C. convoluta* had better dye biosorption capacity than *E. prunastri*. Dye biosorption rate was found as 71.41% at optimal conditions. This study concluded that *C. convoluta* was a successful and cheap biosorbent for treatment of water contaminated by Acid Red P-2BX dye.

KEYWORDS
Acid Red P-2BX; biosorption; lichen; wastewater treatment

Introduction

Treatment of wastewater after industrial use requires new and inexpensive approaches. Textile dyes are the primary contents of the textile wastewater and they are mutagenic and carcinogenic for living organisms [1]. Several physical and chemical methods have been used for wastewater treatment, but they are expensive and inefficient in textile dye removal [2]. Biological treatment methods have proved to be more effective, eco-friendly and cheaper [3]. Some studies concern bacterial [4], algal [5] and fungal [6] biomasses, but apart from this research there has been only one study that examined lichen [7] biomass for treatment of industrial wastewater.

Lichens are the most important examples of symbiotic life in nature. Lichen is the association of a mycobiont (fungus) and photobiont (green alga or cyanobacterium) [8]. The photobiont and mycobiont have some roles that support each other, and so many lichen species can adapt to the different environmental conditions. The photobiont supplies energy via photosynthesis to the mycobiont and the fungus provides water and a safe environment to the alga [9]. In addition, the mycobiont produces various lichen secondary metabolites that typically encrust the hyphal and algal surface of lichen during symbiotic relationship [10]. In the literature, lichens are recommended as indicators for heavy metal pollution [11]. There is only one reported study on the

CONTACT Ülküye Dudu Gül ulkuyedudu.gul@bilecik.edu.tr Vocational School of Health Services, Bilecik Seyh Edebali University, 11230 Bilecik, Turkey

Published online 03 Sep 2018

dye removal ability of lichen *Parmelia perlata* [7]. The aim of this study is to investigate the textile dye (Acid Red P-2BX) biosorption properties of lichen species *C. convoluta* and *E. prunastri* as a function of pH, biosorbent type, dye concentration, contact time, temperature and biosorbent dosage at a batch scale level.

Material and methods

Preparation of dye solution

Acid Red P-2BX (ARP-2BX) dye was supplied from the textile factory in Turkey. The stock dye solution (1000 mg/L) was prepared in distilled water. The stock solution was diluted to the desired concentrations for experiments.

Collection of lichens and biosorbent preparation

Two different lichen species (*C. convoluta* and *E. prunastri*) were tested for determination of their dye biosorption capacities. In the experiments, the lichens collected from the urban forest of Bilecik province (N 400 11.5262′, E 0290 57.962′) were used and the collected lichens were prepared as biosorbent. Two different types of biosorbents were prepared for this study. The first group of biosorbents was cleaned by washing and, then the biomass was dried at 100°C during one night. The second group of biosorbents was kept in the ash oven for 30 min at 500°C. Both of the biosorbent groups were ground to make powder. To ensure that all of the powder particles were of equal size, they were passed through a 0.5-mm sieve and made ready for experiments.

Biosorption studies

All experiments were performed in Erlenmeyer flasks with 100 mL of dye containing solutions. To examine the effect of pH, the prepared experimental solutions with different pH values (2, 4, 6, 8 and 10) were used for dye biosorption. To test the efficiencies of two type of biosorbents as dried and ash, 1 g/L of biosorbents were added into the experimental solutions. In addition, the effect of contact time (30–1440 min), initial dye concentration, biosorbent dosage (1, 2 and 4 g/L) and temperature (25, 35 and 45°C) were investigated in experimental series.

Analytical methods

A spectrophotometer (Labomed INC. 22 model) at 535 nm (the wavelength of observing the maximum absorption peak for dye) was used to analyse the concentrations of dye in solution. The samples (2 ml) were taken at definite times and centrifuged (Hettich EBTA12 model centrifuge) at 4000 rpm for 3 min. The supernatant was used for dye analysis.

The dye biosorption rate (B%) was calculated from Equations (1) and (2):

$$\text{Biosorption rate (B\%)} = (C_o - C_f)/C_o \text{ x } 100 \tag{1}$$

$$q_m = C_o - C_f / X_m \quad (2)$$

q_m: the uptake of dye by a unit mass of biosorbent at any time (mg/g), C_o: initial dye concentration (mg/L), C_f: final dye concentration at any time (mg/L), X_m: the sorbent concentration (g/L).

FTIR analysis

The FTIR analysis was done by an Agilent Technologies, Cary 630 FTIR spectrophotometer. The dried biomasses of lichens (before and after biosorption) were ground into powders (blended with dry spectroscopic grade powders) and then pressed into small disks for FTIR measurements. Samples were scanned at the scan range of 400–4000 cm^{-1}.

Results and discussion

The selection of lichen species and the effect of pH on biosorption

In order to select the most effective lichen biosorbent, the different species were tested for dye biosorption. Optimal pH was found as 2 for both lichen species and biosorbent types (Table 1). The dried lichen biosorbents were also found to be more effective than ash lichen biosorbent for all species. Dried and ash lichen biosorbents were prepared with 100°C and 500°C, respectively.

C. convoluta showed more dye removal activity than *E. prunastri* (Table 1), and so *C. convoluta* was selected for further experiments. As seen in Table 1, ash biosorbents were not effective for both lichen species. It was reported that the high temperature as 500°C provided both the stability of biosorbent and increased surface area of biosorbent [12]. But, the results of our study showed that biosorbents dried at 100°C showed better dye biosorption activity

Table 1. The dye biosorption rate and capacities of lichen species (*C. convoluta*: C_o: initial dye concentration, B (%): biosorption rate, q_m: biosorption capacity).

Lichen	Type	C_o (mg/L)	pH	B (%)	q_m (mg/g)
C. convoluta	Dried	88.14	2	47.97	42.29
C. convoluta	Dried	88.71	4	34.94	31.00
C. convoluta	Dried	88.71	6	32.53	28.86
C. convoluta	Dried	87.71	8	34.04	29.86
C. convoluta	Dried	87.43	10	33.17	29.00
C. convoluta	Ash	86.71	2	46.62	40.43
C. convoluta	Ash	89.00	4	45.10	40.14
C. convoluta	Ash	88.29	6	46.28	40.86
C. convoluta	Ash	85.14	8	36.14	42.85
C. convoluta	Ash	63.71	10	20.04	13.00
E. prunastri	Dried	88.29	2	47.21	41.71
E. prunastri	Dried	88.71	4	34.46	30.57
E. prunastri	Dried	87.86	6	33.50	29.43
E. prunastri	Dried	87.29	8	33.55	29.29
E. prunastri	Dried	88.57	10	28.23	25.00
E. prunastri	Ash	88.15	2	45.22	39.86
E. prunastri	Ash	87.57	4	45.19	39.57
E. prunastri	Ash	88.00	6	45.13	39.71
E. prunastri	Ash	84.86	8	43.27	36.71
E. prunastri	Ash	60.29	10	23.10	14.29

than ash biosorbents dried at 500°C (Table 1). This study did not find that the use of ash as a biosorbent was successful. On the other hand, another research concluded that the increment in temperature caused degradation of some polymers in the surface and also dehydration of hydroxyl groups on the surface [13]. Recently, Zhao et al. [12] determined that the pyrolysis temperature caused reduction of the number of acidic functional groups such as the carboxylic functional groups on the surface. The results of this current study showed that the functional groups on the lichen surface that participated in the dye biosorption were exposed to thermal degradation and the biosorption rate was decreased. The dried biosorbent preparation was also more economic. Heating to 100°C took less energy than heating to 500°C. The biosorption of dye molecules was regulated by electrostatic attractions between oppositely charged molecules and surface functional groups [14]. In the solutions at low pH values, the surface of biosorbent, which was charged positively, interacted with the negatively charged dye molecules [15]. The optimal pH for biosorption of dye molecules on the surface of *C. convoluta* was found to be 2 (Table1).

The effect of dye concentration

The effect of dye concentration on biosorption was examined. The augmentation of dye concentration resulted in *decreasing* of dye biosorption rate (Table 2). Recently, Kulkarni et al. [7] examined the dye biosorption capacity of lichen *P. perlata* and determined that the increment in the dye concentration caused the decreasing of dye biosorption percentage. Similarly, Bilal et al. [16] showed that biosorption capacity of microalgae was decreased by the *increase* of dye concentration. In addition, De Castro et al. [17] reported that dye biosorption by fungi *increased* dye concentration negatively. Lichen is an example of the symbiotic relationship between fungus and alga and it was expected that lichen showed properties similar to those of fungi or algae. The findings of this study were in agreement with others on dye biosorption with both fungi and algae. It was considered that the binding sites on the lichen were saturated with the dye molecules and further dye sorption was inhibited by increasing of dye molecules.

The effect of biosorbent dosage

In order to investigate the effect of biosorbent dosage on biosorption of dye by dried *C. convoluta*, different amounts of biosorbent dosages (1, 2 and 4 g/L) were tested for dye removal capacity. Figure 1 shows the results. Increasing adsorbent dosage caused an

Table 2. The effect of dye concentration on biosorption (C_o: initial dye concentration, B (%): biosorption rate).

Lichen	Type	Co (mg/L)	B (%)
C. convoluta	Dried	54.71	63.71
C. convoluta	Dried	88.14	47.97
C. convoluta	Dried	139.57	26.29
C. convoluta	Dried	147.57	19.86
C. convoluta	Ash	63.43	45.27
C. convoluta	Ash	86.71	46.62
C. convoluta	Ash	139.29	14.26
C. convoluta	Ash	147.29	13.29

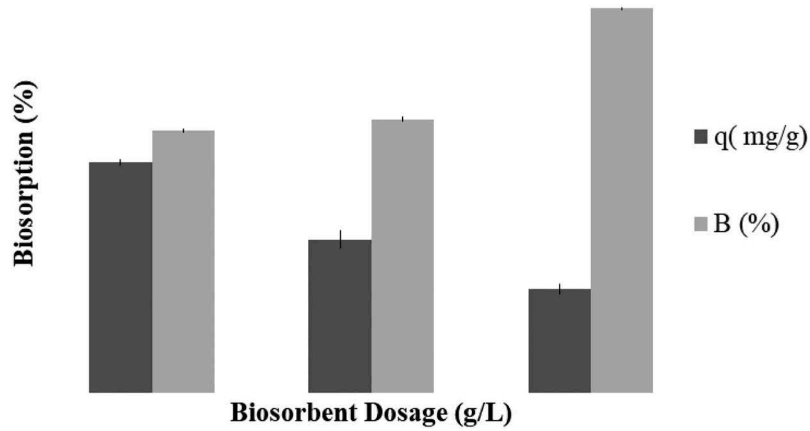

Figure 1. The effect of biosorbent dosage on biosorption (B, %).

increment of dye biosorption percentage. It was previously reported that dye removal was increased while the biosorbent dosage was raised [17].

The effect of temperature and contact time

The biosorption process was operated and then samples were taken at specific times for the examination of the time effect on biosorption. The equilibrium time was determined as 1440 min for dye biosorption by lichen (Figure 2).

In the results of the effect of temperature experiments, it was observed that biosorption rate was decreased by the increment of temperature (Figure 2). In a previous study, the effect of temperature on dye removal by lichen *P. perlata* was tested and it was shown that biosorption percentages were increased by the increment of temperature from up to 50°C [7]. But the results of the study showed that maximum decolourisation occurred at 25°C for *C. convoluta* (Figure 2).

FTIR analysis

Figure 3 shows the FT-IR spectra of *C. convoluta* before and after biosorption. The band presence at 3714 cm^{-1} revealed the presence of –OH and –NH groups, but after biosorption, this band shifted to 3694 cm^{-1} and a wide peak with moderate violence was observed. Changes starting from 700 cm^{-1} indicate one or two weak aldehyde C–H peaks.

Biological wastewater treatment methods suggested the use of biological material for pollutant removal. Compared to other biological materials such as algae, fungi and other vascular plants, lichens have some advantages. They are the association of fungi and algae and can have more tolerance for toxic pollutants than fungi and algae. Wojtuń et al. [18] showed that lichens performed more heavy metal bioaccumulation capacity than vascular plants. The results of our study showed that lichens had an effective dye biosorption capacity and that they can be potential biosorbents for dye removal.

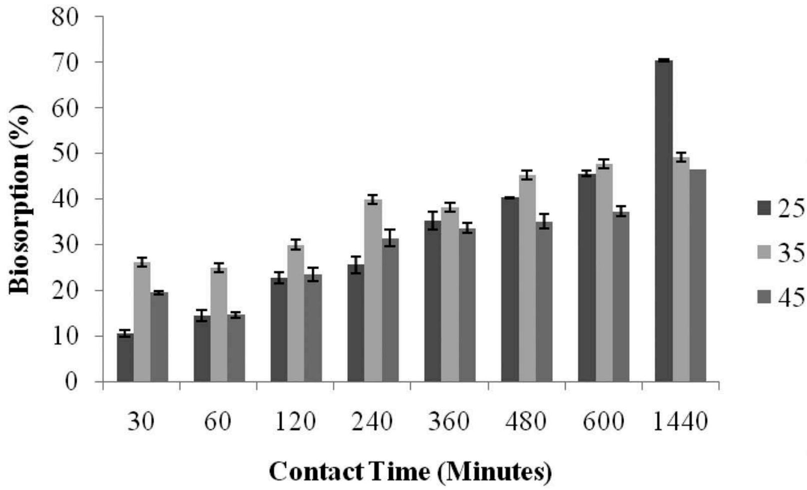

Figure 2. The effect of temperature (25, 35 and 45°C) and contact time (0–1440 min) on biosorption (%).

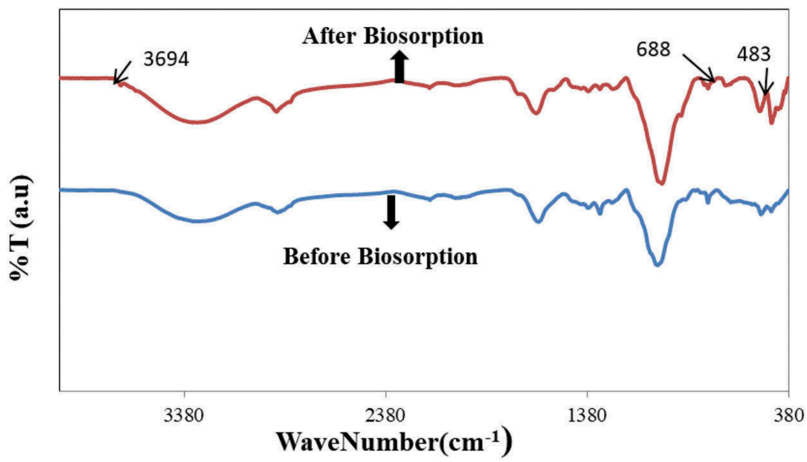

Figure 3. FTIR spectrum of lichen (dried *C. convoluta*) after and before dye biosorption.

Conclusion

This study concerns the determination of a capacity for biosportion of textile dye in two lichen species (*C. convoluta* and *E. prunastri*). It is clear that they are potential low-cost biosorbents. Two types of biosorbents were prepared from lichens. The first was dried at 100°C and the second was prepared as ash at 500°C. The dried lichen was found to be a more successful biosorbent than ash lichen. Further, *C. convoluta* performed more dye removal activity than *E. prunastri*. The optimal conditions for dye biosorption were also determined in this study. It was concluded that *C. convoluta* was acceptable as a low-cost biosorbent for removal of textile dyes from industrial wastewater.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Rani, B., Kumar, V., Singh, J., Bisht, S., Teotia, P., Sharma, S. and Kela, R., 2014, Bioremediation of dyes by fungi isolated from contaminated dye effluent sites for bio-usability. *Brazilian Journal of Microbiology* **45**(3), 1055–1063.

[2] Bharathi, K.S. and Ramesh, S.T., 2013, Removal of dyes using agricultural waste as low-cost adsorbents: a review. *Applied Water Science* **3**, 773–790. doi:10.1007/s13201-013-0117-y

[3] Kooh, M.R.R., Dahri, M.K., Lim, L.B.L., Lim, L.H. and Chan, C.M., 2018, Separation of acid blue 25 from aqueous solution using water lettuce and agro-wastes by batch adsorption studies. *Applied Water Science* **8**, 61. doi:10.1007/s13201-018-0714-x

[4] Kadam, A.A., Kamatkar, J.D., Khandare, R.V., Jadhav, J.P. and Govindwar, S.P., 2013, Solid state fermentation: a tool for bioremediation of adsorbed textile dyestuff on distillery industry waste yeast biomass using isolated Bacillus cereus strain EBT1. *Environmental Science Pollution Research* **20**, 1009–1020. doi:10.1007/s11356-012-0929-6

[5] Daneshwar, N., Ayazloo, M., Khataee, A.R. and Pourhassan, M., 2007, Biological decolorization of dye solution containing malachite green by microalgae Cosmarium sp. *Bioresource Technology* **98**, 1176–1182. doi:10.1016/j.biortech.2006.05.025

[6] Waghmode, T.R., Kurade, M.B. and Govindwar, S.P., 2011, Time-dependent degradation of a mixture of structurally different azo and non azo dyes by using Galactomycesgeotrichum MTCC 1360. *International Biodeterioration and Biodegradation* **65**, 479–486. doi:10.1016/j.ibiod.2011.01.010

[7] Kulkarni, A.N., Kadam, A.A. and Kachole, M.S., 2014, Lichen Permelia perlata: a novel system for biodegradation and detoxification of disperse dye Solvent Red 24. *Journal of Hazardous Materials* **276**, 461–468. doi:10.1016/j.jhazmat.2014.05.055

[8] Lisci, M., Monte, M. and Pacini, E., 2003, Lichens and higher plants on stone: a review. *International Biodeterioration and Biodegradation* **51**, 1–17.

[9] Nash, H., 2008, *Lichen Biology*, 2nd, (New York:Cambridge University Press), 5f.

[10] Bačkor, M. and Fahselt, D., 2004, Physiological attributes of the lichen *Cladonia pleurota* in metal-rich and control sites near Sudbury (Ontario, Canada). *Environmental and Experimental Botany* **52**, 149–159. doi:10.1016/j.envexpbot.2004.01.014

[11] Bajpai, R., Mishra, G.K., Mohabe, S., Upreti, D.K. and Nayaka, S., 2011, Determination of atmospheric heavy metals using two lichen species in Katni and Rewa cities, India. *Journal of Environmental Biology* **32**, 195–199.

[12] Zhao, S.-X., Ta, N. and Wang, X.-D., 2017, Effect of temperature on the structural and physicochemical properties of biochar with apple tree branches as feedstock material. *Energies* **10**(1293), 1–15. doi:10.3390/en10091293

[13] Zhang, J., Liu, J. and Liu, R., 2015, Effects of pyrolysis temperature and heating time on biochar obtained from the pyrolysis of straw and lignosulfonate. *Bioresource Technology* **176**, 288–291. doi:10.1016/j.biortech.2014.11.011

[14] Puchana-Rosero, M.J., Lima, E.C., Ortiz-Monsalve, S., et al., 2017, Fungal biomass as biosorbent for the removal of Acid Blue 161 dye in aqueous solution. *Environmental Science Pollution Research* **24**, 4200. doi:10.1007/s11356-016-8153-4

[15] Gül, Ü.D. and Silah, H., 2014, Comparison of color removal from reactive dye contaminated water by systems containing fungal biosorbent, active carbon and their mixture. *Water Science & Technology* **70**(7), 1168–1174. doi:10.2166/wst.2014.339

[16] Bilal, M., Rasheed, T., Sosa-Hernández, J.E., Raza, A., Nabeel, F. and Iqbal, H.M.N., 2018, Biosorption: an interplay between marine algae and potentially toxic elements—a review. *Marine Drugs* **16**(65), 1–16. doi:10.3390/md16020065

[17] De Castro, K.C., Cossolin, A.S., Dos Reis, H.C.O. and De Morais, E.B., 2017, Biosorption of anionic textile dyes from aqueous solution by yeast slurry from the brewery. *Brazilian Archives of Biology and Technology* **60**, 1–13. doi:10.1590/1678-4324-2017160101
[18] Wojtuń, B., Samecka-Cymerman, A., Kolon, K., et al., 2013, Metals in some dominant vascular plants, mosses, lichens, algae, and the biological soil crust in various types of terrestrial tundra, SW Spitsbergen, Norway. *Polar Biology* **36**, 1799. doi:10.1007/s00300-013-1399-0