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BIOSORBENT BASED ON NONLIVING BIOMASS FOR TEXTILE DYE RETENTION FROM AQUEOUS MEDIA

BY

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Abstract. Due to the benefits of using microorganisms or grafting natural materials as bio-adsorbents, the specialists' attention has been oriented to developing new techniques of bioremediation, as a part of the environment biotechnologies. The article presents the results regarding the biosorptive behavior of non-living biomass (*Saccharomyces cerevisiae*) immobilized in alginate granules for removing different organic dyes (*i.e.* Orange 16, Brilliant Red HE-3B, Rhodamine B, Methylene Blue) from aqueous solution. The biosorption process has been studied in order to establish the optimum conditions of operating process: solution pH, temperature, contact time, initial dye concentration, and type of dye.

Keywords: aqueous media; biosorbent; biomass; biosorption; dye.

1. Introduction

Taking into consideration the trend of using natural materials for wastewaters cleaning techniques, the specialists' attention has been also oriented to developing new bioremediation techniques for polluted natural water

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resources and also treatment of industrial effluents, as a part of the environment biotechnologies (Chajnacka, 2010; Gavrilescu, 2010). These techniques include, among others, the biosorption which remains an open subject for researchers and specialists in the field (Chajnacka, 2010; Deniz, 2015; Mânzatu *et al*., 2015; Camargo de Castro *et al*., 2017; Bilal *et al*., 2018). The main advantage of biological treatment, comparing with certain physical-chemical treatments, is that over 70% of organic matter, expressed by COD_{Cr}, may be converted to biosolids (Șuteu *et al*., 2012). In line with these approaches, the depollution potential of different types of microorganisms opens new emerging biotechnological processes to be further studied and transformed into practical, industrial solutions (Zaharia and Șuteu, 2012; Șuteu *et al*., 2013a; Mânzatu *et al*., 2015; Camargo de Castro *et al*., 2017).

Biosorption is a process of retaining chemical species on biological or natural materials as biosorbents (Șuteu *et al.*, 2012). It is a method achieved through extracellular and intracellular bonding, interactions that depend on the nature of the organic compounds, on the structure of adsorptive materials, on microbial metabolism and on transport process. Similar with the biodegradation of organic compounds, the biosorption implies breakage and formation of new chemical bonds that degrades the original molecular structure of the pollutant.

The main objective of this work is to present the biosorptive behavior of the non-living biomass (*Saccharomyces cerevisiae*) immobilized in alginate granules for removal of different textile dyes (*i.e*. Orange 16, Brilliant Red HE-3B, Rhodamine B, Methylene Blue) from aqueous solution. The biosorption process has been studied in order to establish the optimum conditions of operating process. The effect of various experimental operating parameters such as biosorbent dose, temperature, initial dye concentration, dyes type, particle size and solution`s pH were investigated.

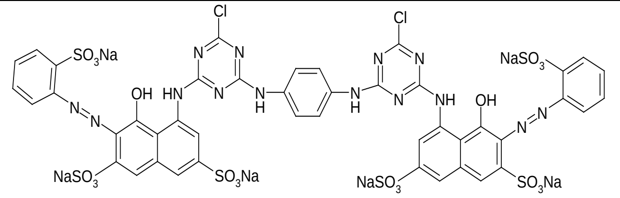
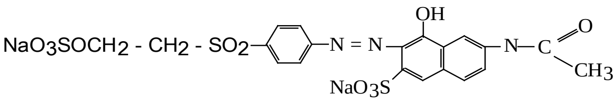
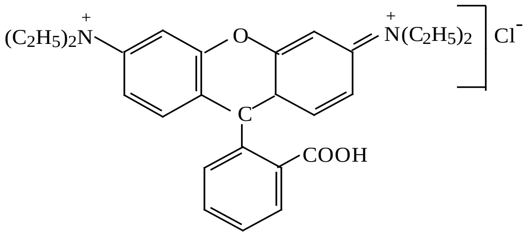
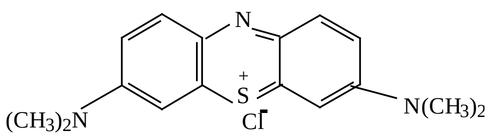
2. Experimental

Materials

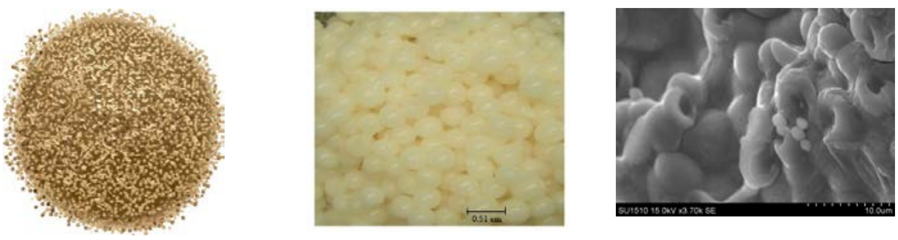
Dyes. The selected dyes: *Brilliant Red HE-3B, Orange 16, Rodhamine B* and *Methylene Blue* were used as commercial products, and are presented and characterized in Table 1. Aqueous stock solutions of dyes, with desired concentration, were prepared using the commercial salt form of the dye and distilled water. The working solutions were obtained from stock solution by dilution with bi-distilled water.

Non-living *Saccharomyces cerevisiae* biomass was treated first with NaOH 0.75 M at 70°C for 15 minutes and then dried for modifying its biosorptive properties by increasing the number of available groups for bonding (Șuteu *et al*., 2013b). The obtained powder was mixed with sodium alginate solution 1% and dripped into a calcium chloride solution in order to obtain biomass immobilised granules (Fig. 1).

Table 1
Structure and Characteristics of the Selected Plants

Structure	Characteristics
	**Brilliant Red HE-3B** (Reactive Red 120); C.I. 25810; MW = 1463 g/mol; λ_{max} = 530 nm; Concentration of the stock solution – 500 mg/L
	**Orange 16** C.I. 18097; Reactive anionic dye; MW = 735.6 g/mol; λ_{max} = 560 nm; Concentration of the stock solution –715 mg/L
	**Rhodamine B** (Basic Violet 10) ; C.I. 45170; xantenic dye; MW = 479.2 g/mol; λ_{max} = 550 nm; Concentration of the stock solution – 479 mg/L
	**Methylene Blue** (Basic Blue 9); C.I. 52015; Cationic, phenothiazine dye MW = 319.85 g/mol; λ_{max} = 660 nm; Concentration of the stock solution – 320 mg/L

Note. Abbreviations: Bred - Brilliant Red HE-3B; O16 - Orange 16; RhB – Rhodamine B; Methylene Blue - MB



a *b* *c*

Fig. 1 – Biosorbent : (*a*) powder of non-living biomass (*Saccharomyces cerevisiae*); (*b*) granules of non-living biomass (*Saccharomyces cerevisiae*) immobilized in alginate; (*c*) ESEM images for non-living biomass (*Saccharomyces cerevisiae*) immobilized in alginate.

Experimental methodology

The biosorption experiments were performed through a simple batch method presented schematically in Fig. 2, wich consists in contacting different amounts of biosorbent with 25 mL of aqueous solution with a variety of dye concentrations. The dyes solutions' pH was adjusted at the required value by adding HCl or NaOH 1N aqueous solution, and was measured with a RADELKIS OP-271 pH/Ion analyzer. The aqueous systems with two phases were maintained in a thermostatic bath and under discontinuous stirring.

The biosorption efficiency of the non-living biomass *(Saccharomyces cerevisiae)* immobilized in alginate granules was evaluated by determined the *amount of dye adsorbed* q (mg/ g) (1) and by *percentage of dye removal*, R (%) (2):

$$q = \frac{C_0 - C}{G} \cdot V \quad (1)$$

$$R = [(C_0 - C)].100 / C_0 \ (\%) \quad (2)$$

where: C_0 and C are initial and the equilibrium concentration of dye in solution (mg/L), G is the amount of biosorbent (g) and V is the volume of solution (L).

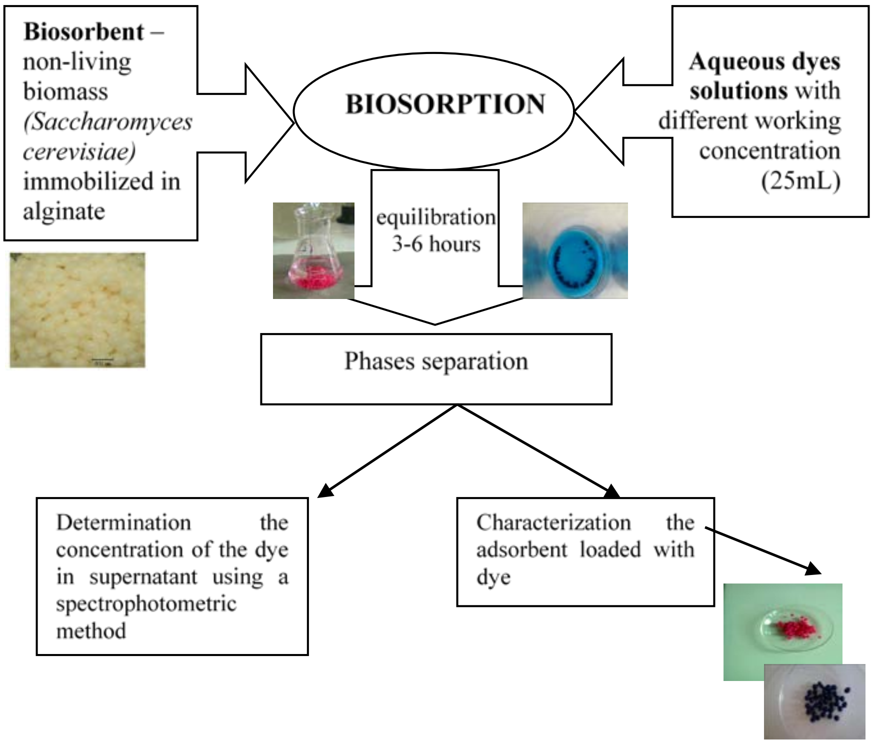


Fig. 2 – Biosorption schematic methodology.

3. Results and Discussions

Effect of solution pH, contact time and type of dye

The solution pH is an operational parameter significant in the study of the biosorption process, because his value generates both the biosorbent surface morphology through availability of the characteristic functional groups into a particular ionic form, and also the ionic form of the species to be retained. The effect of initial solution pH on the biosorption of dyes onto non-living biomass *(Saccharomyces cerevisiae)* immobilized in alginate was examined and the results are presented in Fig. 3. The results presented in Fig. 3, shows that the anionic dye could be better retained from acidic media (around of pH 2) and for cationic dyes it was efficient the biosorption from slightly basic media. Also, regardless of pH it is observed that the amount of dye increases with contact time and depends on the structural type of dye (anionic or cationic) and how great/heavy is the colorant (for example red dye and orange dye).

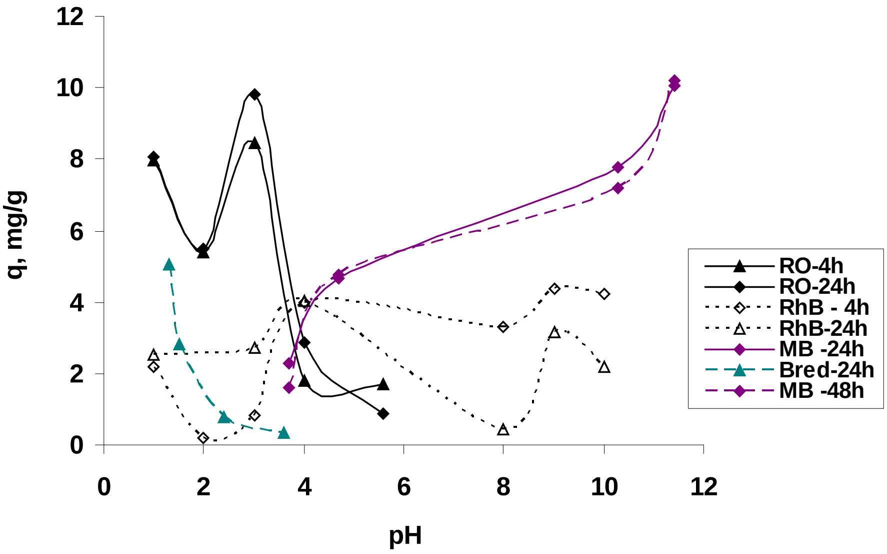


Fig. 3 – Effect of pH, contact time and type of dyes on the biosorption onto immobilized biomass (T = 25°C): RO: C_0 = 30.6 mg/L; RhB: C_0 = 9.68 mg/L; BRed: C_0 = 20 mg/L; MB: C_0 = 30 mg/L.

Effect of biosorbent dose and phases contact time

To investigate the effect of non-living biomass dose (*Saccharomyces cerevisiae*) immobilized in alginate on the removal capacity of dyes from aqueous solutions in the established concentrations and favourable pH, biosorption experiments were carried out with different biosorbent amounts for 3-6 h. The results, presented in Fig. 4, showed that the dyes amount biosorbed per mass unit of biomass decreases with the increase of the amount of biosorbent. An amount of 0.2 g biosorbent (wet substance)/L assures adequate biosorption capacity and was chosen for following experiments. Also, an increase in the amount of biosorbed dyes with the increase of phase contact time is also observed.

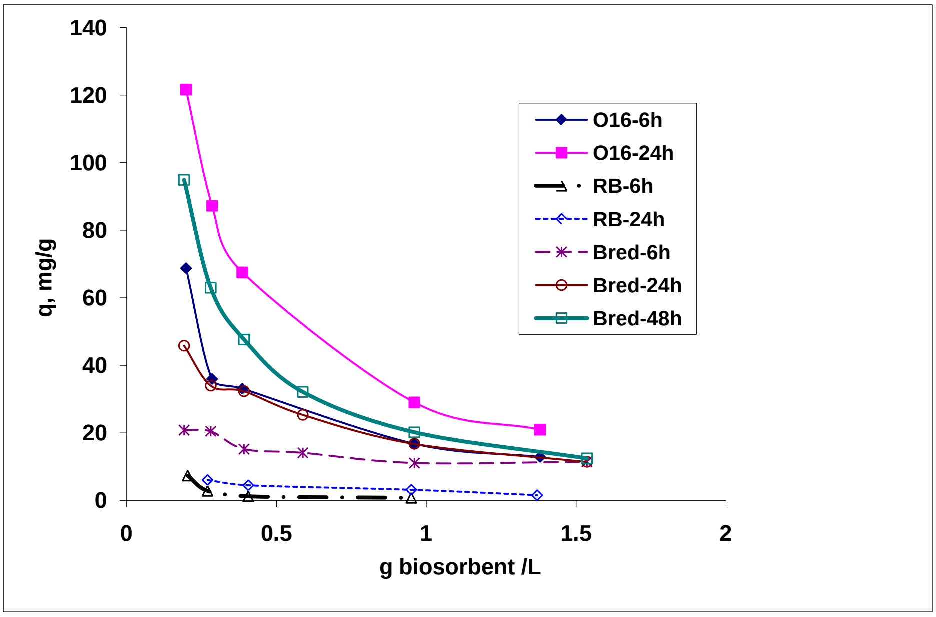
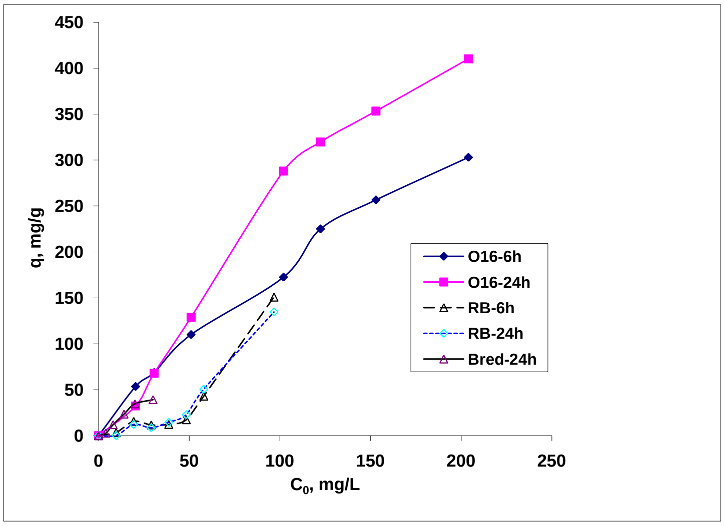


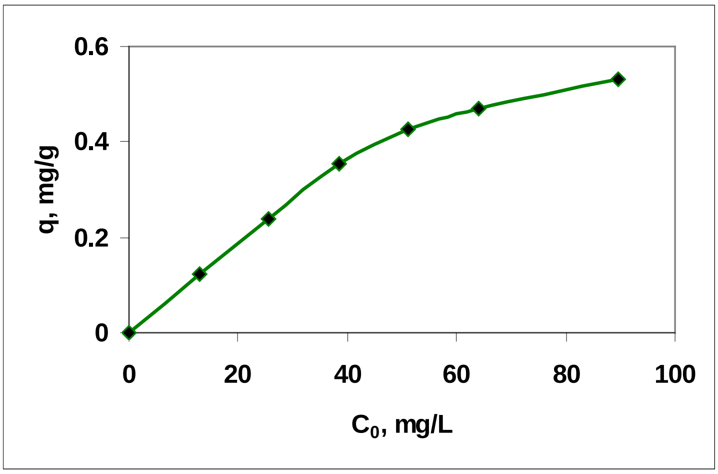
Fig. 4 – Effect of biosorbent dose on the biosorption of dyes onto biomass immobilized:
RO: C_0 = 30.6 mg/L; pH = 2; T = 25°C; RhB: C_0 = 9.68 mg/L; pH = 3, T = 25°C; BRed: C_0 = 20 mg/L; pH = 2, T = 25°C.

Effect of initial dye concentration and the type of studied dye

From Figs. 5*a* and *b* it can be observed an increase in adsorption capacity with the increase of the initial dyes concentration, and also a clear difference between the adsorption capacity as a function of the type of dye and its molecular weight. Thus, for example, between the two reactive dyes is better retained *Orange 16 dye*, less voluminous and capable of shedding on the pore size of the biosorbent material. It is also be observed, in Fig. 5, the influence of the phases contact time on the biosorption of the dyes onto biomass immobilized.



a



b

Fig. 5 − Effect of initial dyes concentrations on the biosorption onto immobilized biomass:
(*a*) RO: pH = 2; T = 25°C; RhB: pH= 3, T = 25°C; BRed: pH = 2, T = 25°C; (*b*) MB: pH = 5.6, T = 20°C.

3. Conclusions

Preliminaries investigation of some organic dyes biosorption onto *Saccharomyces cerevisiae* biomass immobilized on alginate beads allowed the following conclusions:

❑ Alginate immobilization of biomass granules leads to an efficient biosorbent in dye and color removing from different wastewaters.

❑ The biosorption capacity of the immobilized biosorbent is influenced by initial solution pH, dye concentration, dose and particle sizes of biosorbent types of dyes (structure) and phases contact time.

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BIOSORBENT PE BAZĂ DE BIOMASĂ MOARTĂ PENTRU REȚINEREA COLORANTULUI TEXTIL DIN MEDIU APOS

(Rezumat)

Datorită beneficiilor utilizării microorganismelor, sau grefării materialelor naturale și folosirii drept biosorbenți, atenția specialiștilor a fost orientată spre dezvoltarea de noi tehnici de bioremediere, ca parte a biotehnologiilor de mediu. Lucrarea prezintă rezultatele privind studierea comportării biosorbtive a biomasei moarte (*Saccharomyces cerevisiae*) imobilizată în granule de alginat pentru reținerea diferiților coloranți organic (*i.e.* Orange 16, Brilliant Red HE-3B, Rhodamine B, Methylene Blue) din soluția apoasă. Procesul de biosorbție a fost studiat în vederea stabilirii condițiilor optime de operare: pH-ul soluției, temperatură, timp de contact, concentrație inițială de colorant și tipul de colorant.