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Nonionic microemulsion systems applied for removal of ionic dyes mixtures from textile industry wastewaters

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ABSTRACT

Pollution abatement of wastewaters discharged from textile industry remained a serious environmental problem susceptible for further technological improvements. This study proposes an innovative, fast and efficient microemulsion system for removal of ionic dyes mixture from such wastewaters.

A series of physical–chemical parameters (initial dye concentration, pH, salt and sequestrant concentrations) with significant influence on the dye removal efficiency of water/nonionic surfactant/ethyl acetate ternary system has been studied in order to find out the optimal compositions for an efficient extraction of cationic and anionic dyes from aqueous media. The optimum extraction conditions for this system correspond to pH > 5, surfactant concentration around 8% (w/w) and organic phase concentration around 13% (w/w), resulting in extraction efficiencies around 90%. By adding sodium chloride (concentration > 60 g/L) in the ternary system the removal efficiency was improved.

1. Introduction

The removal of color from dyehouse wastewater is currently one of the major problems faced by the textile industry [1–4]. The textile dyeing and finishing industry has created a huge pollution problem as it is one of the most chemically intensive industries on earth, and the principal polluter of clean water (after agriculture). The daily water consumption of an average sized textile mill having a production of about 8000 kg of fabric per day is about 1.6 million liters [5]. The stability and resistance of dyes to degradation has made color removal from textile wastewater difficult by conventional biological treatment plants and considerable research is focused on addressing this problem [1,6]. Among various new techniques used for color removal, extraction by microemulsion has been introduced as an innovative and very efficient method [1,7,8].

Microemulsions have a wide variety of applications ranging from oil recovery to food, cosmetics, biotechnology, detergency, nanomaterials synthesis and environmental remediation [9–14]. Microemulsions are optically isotropic and thermodynamically stable colloidal systems in which water and oil may coexist in a single phase by the addition of a surfactant with an appropriate hydrophile-lipophile balance [15]. Microemulsion extraction systems offer several advantages compared to the conventional solvent extraction such as: efficiency, enhanced selectivity, no need of processing at high temperature or pressure, cost effective and less time consuming.

A detailed study has been carried out in this paper to determine the best composition and the optimal conditions for dye removal from textile wastewaters using the extraction in microemulsion systems. Anionic dye Methyl Orange and cationic dyes Crystal Violet and Rhodamine B, respectively, as being largely present in the dyeing process and rinsing effluents of the textile industries were selected as being representative for this study [16–19]. The surfactant was chosen from nonionic class (polyoxyethylene (4) lauryl ether) and the organic phase required to form the microemulsion system was ethyl acetate. Nonionic surfactant was used since it has a low toxicity and exhibits better solubility properties in microemulsion systems [20]. Moreover, nonionic surfactants have the ability to form microemulsion without the assistance of co-surfactant. Ethyl acetate has several advantages: it is manufactured on a large scale for use as a solvent; it is very volatile so it can be removed from a sample by heating; its LD_{50} for rats is 11.3 g/kg, indicating low toxicity.

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In the present work the extraction in microemulsion technique has been used in order to remove mixture of dyes from textile wastewaters. In order to simulate the practical working conditions of a water treatment plant, the effect of several factors on removal efficiency was studied: initial dye concentration, pH, inorganic and organic compounds concentrations. To the best of our knowledge, no study has been reported on the use of nonionic microemulsions for color removal of a mixed dyes solution composed by ionic dyes. Moreover, the nonionic microemulsions are able to reduce the level of pollutants from wastewaters with the purpose of reaching the standards established by the environmental regulations in a very short time with the possibility to reuse the cleaned water in the industrial circuit without additional treatment steps.

2. Materials and methods

2.1. Materials

Ethyl acetate (EtOAc) 99.8%, Rhodamine B (Rh B) dye, sodium hydroxide (NaOH), sodium chloride (NaCl) and hydrochloric acid (HCl) were purchased from Sigma–Aldrich. Crystal Violet (CV) and Methyl Orange (MO) dyes were obtained from Riedel-de Haen and ethylenediaminetetraacetic acid (EDTA) was bought from Fluka. Polyoxyethylene (4) lauryl ether (Brij 30) and polyethylene glycol tert-octylphenyl ether (TX-114) were provided by Acros Organics. Distilled water was used for the preparation of the microemulsion samples. All chemicals were used as received without further purification. The chemical structures of dyes and surfactant used in this work are presented in Fig. 1.

2.2. Methods

2.2.1. Extraction procedure

The pseudo ternary phase diagrams represent the first step in analysing a multi-component heterogeneous system. The Winsor II (WII) compositions used in this study are shown in Table 1 and they have been chosen from the ternary phase diagrams published elsewhere [7]. The detailed experimental extraction can be described briefly as follows: the WII microemulsion was prepared using nonionic surfactant (Brij 30), organic phase (EtOAc) and a mixed dyes solution (aqueous phase). The extraction experiments were carried out in a scale-lab glass reactor. The reactor was equipped with four valves: one for wastewater supply, one for ethyl acetate and Brij 30 supply, one for clean water evacuation and one for air injection. During the extraction process all four valves were closed in order to preserve the composition of the system, as the ethyl acetate is a volatile compound. The microemulsion was stirred until the equilibrium of mixed dyes solution distribution was achieved. The equilibrium was checked by monitoring the separation of two clear phases (visual inspection): the upper phase, represented by the water-in-oil microemulsion, which is strongly colored, and the colorless aqueous phase (down phase). A schematic representation of the extraction process is illustrated in Fig. 2.

Table 1
Winsor II compositions for dye aqueous solutions/Brij 30/EtOAc systems.

Composition	EtOAc % w/w	Brij 30% w/w	Water % w/w	Brij 30/EtOAc ratio
5 mg/L dye				
1	12.61	8.01	79.38	0.71
2	17.02	7.34	75.64	0.48
3	21.31	7.70	71.00	0.40
4	21.79	21.74	56.48	1.11
5	28.94	11.36	59.70	0.44
6	33.42	10.89	55.69	0.37
7	37.29	12.09	50.62	0.36
10 mg/L dye				
1	8.31	8.60	83.08	1.16
2	18.46	20.04	61.50	1.21
3	24.95	10.40	64.65	0.46
4	29.09	10.90	60.00	0.42
5	33.14	11.66	55.21	0.39
6	38.35	9.59	52.06	0.28
25 mg/L dye				
1	8.56	5.85	85.59	0.76
2	29.11	10.83	60.06	0.41
3	32.43	13.53	54.04	0.46
4	36.44	14.09	49.47	0.43
5	36.82	22.28	40.90	0.67

The extraction experiments were performed at room temperature. The dyes solution was obtained by mixing three ionic dyes, Crystal Violet, Methyl Orange and Rhodamine B aqueous solutions with concentrations in the range 2–25 mg/L.

The influence of some physical–chemical parameters on the extraction efficiency has been investigated as follows: concentrations of single and mixed dye solutions, pH, NaCl concentration

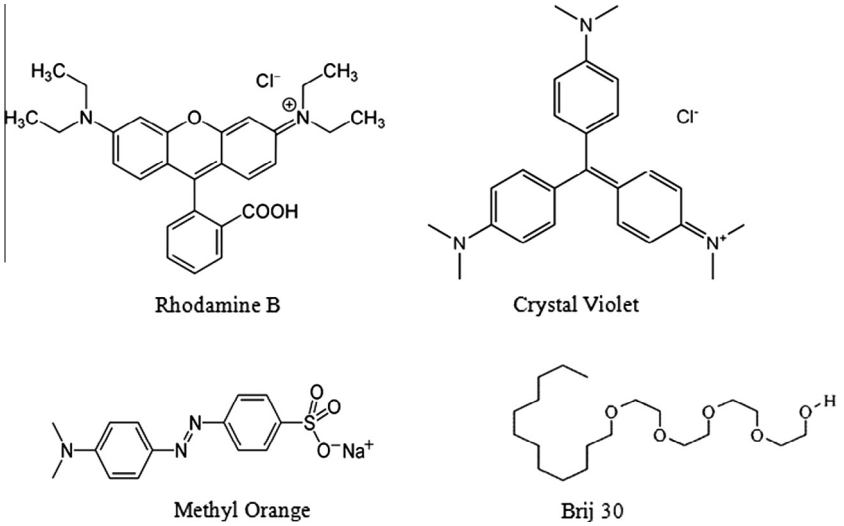

Fig. 1. Chemical structures of Rhodamine B, Crystal Violet, Methyl Orange and Brij 30.