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Concentration of organic contaminants by ultrafiltration

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Abstract

The results of concentration experiments on model dye solutions containing anionic surfactant and mineral salts were reported. The objective of the study involved recovery of valuable substances and water reuse. The membrane efficiency as well as dye and surfactant rejections during concentration tests were evaluated. The Mollsep Fiber (Nadir) modules with membranes made of polyethersulfone (10 and 30 kDa) were used in the experiments. The anionic surface active agent (sodium dodecyl sulphate) and sodium chloride (NaCl) were added to the dye (Direct Black) solutions. The concentration experiments were conducted at 0.1 MPa. The effect of concentration factor on the volume flux of dye solutions, dye and surfactant rejection was studied. It was found that membrane permeability and dye separation factor was kept constant during concentration process for all experimental solutions. Surfactant retention was highly influenced by solution composition and subjected to great variations. Nevertheless, it was possible to receive two streams in UF process: concentrated dye solutions and water containing anionic surfactant (SDS).

Keywords: Ultrafiltration; Concentration process; Anionic dye; Sodium dodecyl sulfate; Concentration factor

1. Introduction

Many industries, such as dyestuffs, textile, paper and laundry generate a considerable amount of colored wastewater. It is quite obvious that public perception of water quality is highly influenced by the color. The presence of very small amounts of organic dyes in water, even at concentrations less than 1 g/m^3, is visible and undesirable [1]. More than 700,000 tones of dyes are produced annually and two per cent of this production are discharged directly to water streams [2]. Because of increasingly stringent restrictions on the organic content of industrial effluents it is necessary to eliminate organic load from wastewater before it is discharged.

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Furthermore, used dye and rinsing baths may contain also high quantities of auxiliary organic and mineral compounds (detergents, salts, acids, hydroxides, dispersing and complexing agents, etc.). Purification of these complex effluents is therefore highly advisable, in view of the decrease of wastewater volume, as well as the reuse of valuable substances. It should be pointed out that discharging the wastewater purified with the use of conventional technologies (coagulation, adsorption, active sludge [1,3]) is rather inefficient and contributes to the lost of valuable raw materials.

Membrane technology is being increasingly used in the treatment of textile and laundry wastewater. Although a number of studies have been carried out involving the application of pressure membrane processes in water reuse [4–10], only a few papers deal with recovery of valuable components from exhausted dye or rinsing baths, mostly with the use of nanofiltration [11–14]. The possibility of concentrating dye solutions, as well as saving water, auxiliaries (mostly salts) and energy by utilization of commercially available nanofiltration membranes has been showed [13]. It is interesting to note that in principle there is no literature available on the application of low-pressure membrane processes (microfiltration, ultrafiltration) in the industrial reuse of valuable chemical compounds of exhausted dye or rinsing baths. Merely the recovery of polymeric dyes and low-soluble dyes (indigo) in ultrafiltration process was reported as an efficient process in industrial applications [14]. Also Porter and Gomes [15] found (in laboratory experiments) that it was possible to retain anionic dyes by ceramic microfilters and polymeric ultrafiltration membranes.

It should be stressed out that satisfactory applications of membrane processes to the treatment of complex dye effluents requires wastewater fractionation into three streams (at least): concentrate — rich in organic compounds, permeate — rich in mineral salts, and pure water permeate. Adoption of such a procedure needs extensive investigations on process efficiency, depending on the molecular interactions between components of the treated solutions. However, only a few papers are focused on the dye and surfactant retention from aqueous dye-detergent mixtures. Most of the investigations deal with MEUF (micellar enhanced ultrafiltration) [16–18], in which only successful organic dye removal is important, whereas data on surfactant rejections are passed over. Generally, in MEUF complete surfactant retention is assumed, because surfactant concentrations are enough high to form large micells. If the surfactant concentration is below the critical micellar concentration (CMC), what usually occurs in real waste effluents, small surfactant monomers appear in the treated solutions. In such a case, the mechanism governing the dye and surfactant retention will be the results of the molecular interactions between the solution components, as well as the interactions between the dye/surfactant molecules and membrane material. The steric and charge effects may lead to unexpected high retentions of solutes. The influence of charge shielding, due to presence of mineral salts should also be taken into account. Van der Bruggen et al. [12] found that the ionic strength as well as the presence of cationic surfactants in dye baths had only a minor influence on cationic dye retention. On the contrary, Khamis et al. [19] found that the presence of dyes and surfactants of the same charge in the treated solutions had positive effect on membrane retention. Tang and Chen [7] confirmed that dye rejection remained almost constant regardless of what salt concentration is used. However, Akbari et al. [20] observed a distinct decrease of dye separation factor with the increasing concentration of mineral salts in the treated solution. Koyuncu et al. [21] showed that various mechanisms (cake formation or adsorption) were responsible for flux decline during nanofiltration of dye and salt mixtures characterized by different ionic strength.

Taking into consideration the poor literature data on applying low-pressure membrane