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ULTRAFILTRATION OF MICELLE-FORMING DYE

1. INTRODUCTION

Pressure-driven membrane operations such as reverse osmosis and ultrafiltration are used in modern industry because of their ability to separate and concentrate particles. Furthermore, solute separated in this way can very often be directly recycled and reused. This is of considerable importance both from the ecological and economical point of view. Ultrafiltration is a well-established technique for concentrating dilute macromolecular solutes or particles. It can successfully be applied to smaller molecules as well. The molecular weight of the majority of dyes used in textile industry is in the range between typical reverse osmosis and typical ultrafiltration applications. Some dyes behave similarly to surfactants forming aggregates in water solutions [1]. Dye aggregates are much easier to obtain than single molecules. So it is desirable to intensify the aggregation.

The purpose of our work is to determine the feasibility of improving the retention of dye by factors known to influence the micellization of surfactants [3].

2. EXPERIMENTAL

Ultrafiltration experiments were performed in cross-flow ($15\,cm^2$) of flat membrane area. The cell was equipped with magnetic stirrer. Pressure (100 kPa) exerted on the bulk solution was supplied by a cylinder of pressurized nitrogen. The cellulose acetate membranes that were used in this study were the products of VEB Zellstoff- und Zellwollwerke Wittenberge, East Germany (cut-off 900 daltons).

The dye used was a commercial, textile dye – Acid Green (C.I.61570) of molecular weight 578. Two dye concentrations of 110 mg/dm^3 and 600 mg/dm^3 were employed in the experiments. For each concentration the influence of 3% NaCl and 0.1% Rokwinol 60 on retention coefficient in the range of temperatures from 10°C to 40°C was studied. The nonionic surfactant Rokwinol 60 (polyoxyethylene sorbitan monostearate) was provided by Rokita, Poland. The concentration of dye was measured photometrically.

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3. RESULTS AND DISCUSSION

For Acid Green the dependence of the retention coefficient on solute concentration is similar to that for micelle-forming substances [2]. At low concentration when only monomers are present in the solution, the retention coefficient decreases with the increase of flow concentration. When the concentration is high enough, aggregates of solute molecules start to form near the membrane surface. Large aggregates (micelles) are completely retained by the membranes. The number of micelles is proportional to the solution concentration, so the retention coefficient increases with the feed solution concentration. Combination of the two phenomena gives the resuling curve in fig. 1.

The influence of factors affecting micellization was studied in two characteristic points, i.e., on the decreasing part of the curve in fig. 1 (a concentration of 110 mg/dm^3) and on the increasing part of the curve (a concentration of 600 mg/dm^3). The retention coefficient versus temperature is shown in figs. 2 and

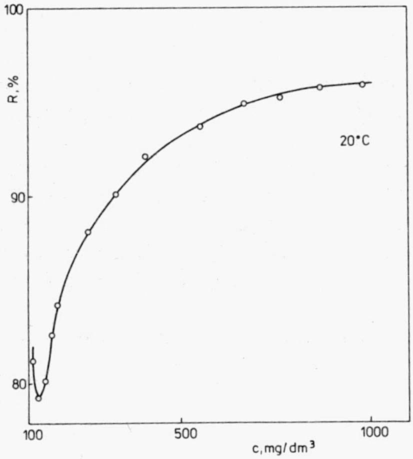

Fig. 1. Retention vs. feed solution concentration

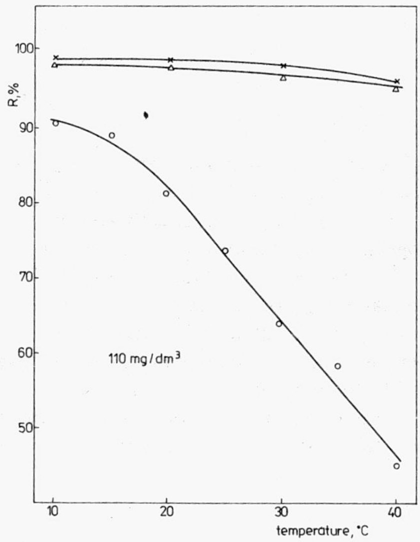

Fig. 2. Retention of dye in different temperatures. Bulk solution concentration – 110 mg/dm^3

Additives: ○ – none, x – 3% NaCl, △ – 0.1% Rokwinol 60

3. It is known that the temperature raises CMC (critical micelle concentration) of the ionic surfactant [3], and diminishes micellar dimension. Probably the same mechanism is involved in the case of Acid Green. At the concentration of 110 mg/dm^3, an increase in temperature significantly reduces the number of aggregates in the solution, and the resulting retention becomes the retention of single dye particles.

At a higher concentration the effect of temperature is less significant. The majority of dye molecules are in aggregate form. An increase in CMC, however, causes an increase in the concentration of free molecules which can pass through the membrane.

The presence of nonionic surfactant, Rokwinol 60, makes the retention very high and stable in the whole range of temperatures for studied dye concentrations. This effect may be due to formation of mixed micelles and to entrapment of dye monomers inside the surfactant micelles.

The presence of electrolyte has been reported to improve the formation of micelles [3], however, NaCl significantly increases the retention at small dye concentration only. This effect is not observed at high concentration of the dye.

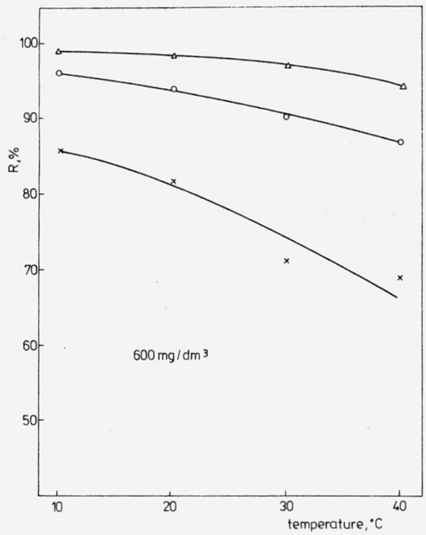

Fig. 3. Retention of dye in different temperatures. Bulk solution concentration – 600 mg/dm^3

Additives: ○ – none, x – 3% NaCl, △ – 0.1% Rokwinol 60

4. CONCLUSIONS

When ultrafiltration of dye solutions is performed by means of membranes which do not ensure sufficient retention of single dye molecules, the efficiency of the operation can be improved by addition of nonionic surfactant. In this case the retention coefficient is not dependent on temperature and solution concentration. The use of nonionic surfactant is particularly recommended when initial dye concentration is small and the temperature is high.

An electrolyte (NaCl) improves retention when the bulk solution concentration is below the CMC (critical micelle concentration) value.

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