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Research Article

Recovery and Recycle of Water from Dye Effluent by Partial Crystallization at Sub-Ambient Temperature

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Abstract

Experiments were conducted for recovery of water from real dye effluents. The dye effluent was collected from an industry at Namakkal, Tamilnadu, India. The effluent was diluted with water to various concentrations. All the dye solutions were subjected to freeze concentration in freezer until one third of the dye solution was converted to solid phase. The concentration of solid phase and liquid phase so formed by partial freezing were compared with that of the dye solution before freezing. It was observed that the solid and liquid phases had different concentration of dye. The concentration between solid and liquid phase was found to increase with increase in concentration of the original dye effluent. After partial freezing, the concentration of the dye effluent was higher in the solid phase that in the liquid phase. The results of the study showed that freeze concentration for the recovery and reuse of waste water from dye effluents will be a good alternative to many old techniques and also environmental friendly.

Keywords: Wastewater; Dye effluent; Partial crystallization; Freeze-separation; Biological oxygen demand; Chemical oxygen demand.

Introduction

The concentration of a solution plays an important role in terms of transportation, conservation and manufacturing in food industry, and also for desalination and waste liquid treatment. Freeze concentration is a process of concentrating liquid products by freezing the water content and subsequently removing the so-formed ice crystals. The ice crystals are pure than the solution [1]. The freeze concentration is a physical separation technique that involves the fractional crystallization of water and subsequent removal of ice [2-4].

Literature shows that in terms of both the construction and operation of the equipment, freeze concentration in a one-step configuration has emerged as an interesting alternative to conventional processes. Water is an essential resource to humans. Two major problems currently facing industrial water users are scarcity of water and the deterioration of the quality of the available water [5]. The textile industry is a sector of high water consumption and the ability to treat wastewaters from this industry more effectively than at present would be beneficial in alleviating water shortages since more water will be available for other uses. The wastewaters from the textile industry are a major source of pollution because of the high concentrations of inorganic and organic chemicals, including residual dye stuffs [6,7]. So, the need for implementation of such a technique to recover water from effluent is the lack of fresh water for industries in various parts of the world. There it is also important to apply freeze separation technique for desalination [8].

The development of energy-efficient desalination methods is of paramount importance to solve these complex problems as the world is currently facing the prospect of a severe global shortage of fresh water alongside finite energy resources [9]. From an industrial-separations point of view, the freeze concentration process has a number of important advantages [10, 11]. a) A high separation factor, b) High energy efficiency as the latent heat of freezing is low when compared to the latent heat of evaporation

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(333.5 kJ/kg and 2256.7 kJ/kg, respectively, leading to lower energy requirement in comparison to other processes, c) No biological fouling, scaling and corrosion problems, which means less use of chemicals and thus lower operating costs. d) Low operation cost. The freeze separation also serves as a method for producing food concentrates with high quality as compared to evaporation and membrane technology. Freeze separation is also used to concentrate dilute salt in snow melt water and sand recycling wash water into concentrated salt solution that will be supplemented with crystal salt to treat recycled road sand [12]. Many treatments have been investigated by researchers for their effectiveness in either removing dyes from dye-containing effluents or decolorizing [13, 14]. The present work was carried out to find the effectiveness of freeze concentration technique in the recovery and recycle of water from dye effluent.

Material and methods

Dye effluent preparation and characterization

In order to the recovery of water from textile wastewater by partial crystallization, dye effluent, real dye effluent was collected from the district of Namakkal, Tamilnadu, India. The total dissolved solids (TDS) content of the dye effluent was measured using TDS meter. The dye effluent was diluted to with distilled water to get dye effluents with different TDS content from 600 ppm to 3600 ppm, with an increment of 600 ppm. The biological oxygen demand (BOD), and chemical oxygen demand (COD) of each solution were measured. A double-beam UV visible spectrophotometer (Elico SL244, India) was used for measuring the absorbance of the solution.

Partial crystallization

The dye solutions of known concentration were cooled in freezer until the solution is partially frozen (the solution was cooled until approximately 1/3 of the original volume of the solution was frozen) and the liquid and solid phases so formed were separated and analyzed [15-17]. There are many methods available for determining the unknown concentration of dye solutions. In this study, a double-beam UV-Spectrophotometer was used to determine the concentration of solutions before and after freeze separation. A calibration chart of absorbance versus concentration of the dye effluent was prepared for determining the unknown concentration of the resulting solutions after partial crystallization by interpolation method.

Results and discussion

The experimental data for the study of freeze concentration technique for recovery and recycle of water from dye effluent were analyzed very carefully and the results are presented in the form of graphs. The variation of absorbance of the dye effluent with the concentration of the dye effluent is presented in Fig. 1. It is observed from the results that the absorbance of the solution increases with increase in concentration of the dye effluent. This is attributed to the fact that the absorbance of the pure and clear water is usually less and it tends to increase with increase in concentration of impurities.

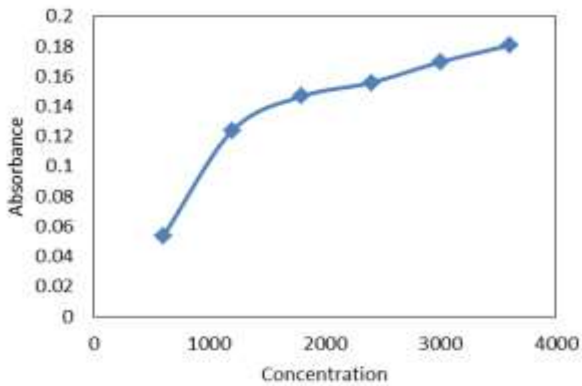

Fig. 1. Effect of initial concentration of the dye effluent on absorbance

The effect of chemical oxygen demand (COD) of the dye effluent on the concentration of impurities in dye effluent is presented in Fig. 2. It can be inferred that the increase in concentration of the impurities in water increases the chemical oxygen demand (COD) of the dye effluent.

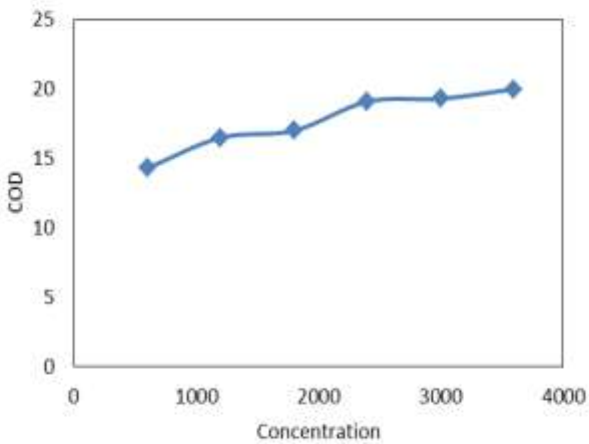

Fig. 2. Effect of initial concentration on chemical oxygen demand of the dye effluent

Fig. 3 shows the effect of concentration of dye effluent on biological demand of the dye effluent. It is observed from the results that the biological oxygen demand of the dye effluent increases with increase in concentration of the dye effluent. From Fig. 2 and Fig. 3, it can be clearly noticed that the chemical oxygen demand (COD) of the dye effluent is greater than the biological oxygen demand (BOD) of the dye effluent.

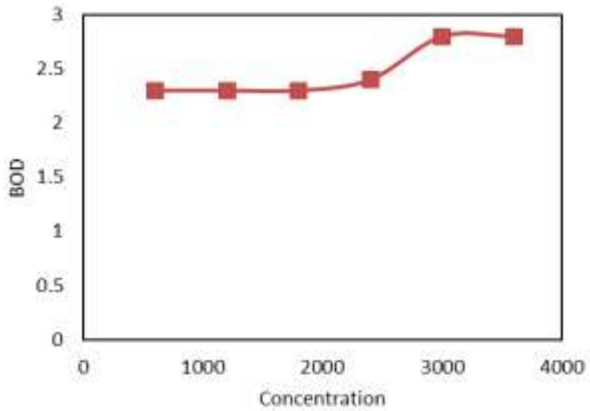

Fig. 3. Effect of initial concentration on biological oxygen demand of the dye effluent

Fig. 4 presents the comparison between the variations of absorbance of the solid and liquid phases, obtained by partial crystallization, with variations in initial concentration of the dye effluents. It is observed that there is a considerable degree of separation effected when the dye effluent is partially frozen. It is also observed that the difference between the concentrations of the solid and liquid phases (resulting due to the partial crystallization) increases with increase in initial concentration of the dye effluent.

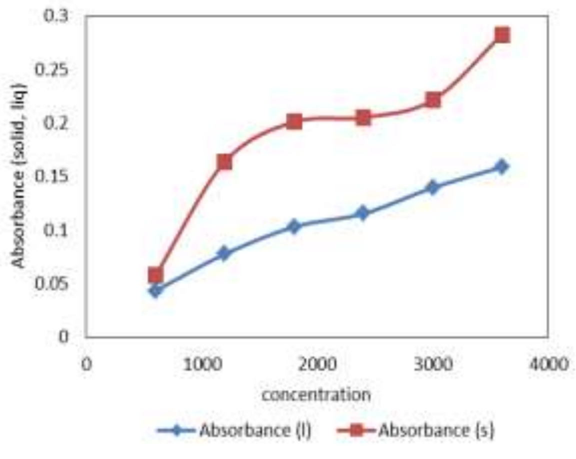

Fig. 4. Effect of initial concentration of the dye effluent on the absorbance of solid (ice) phase and liquid phase

Conclusions

The results of the experiment shows that when a dye solution is frozen partially (crystallization at sub-ambient temperature), the resulting liquid and solid phases have different concentrations. The concentration difference between solid and liquid phase was found to increase with increase in concentration of the original dye effluent. It was observed from the results that the difference between the concentration of dye in the solid and liquid phases was high at higher concentrations of dye solutions. It is expected that partial crystallization could be included as one of the important stages in the recovery and recycle of water from dye effluent. It is also expected that freeze separation would be a better alternative for treatments used for color removal of dye solutions without the use of chemical agents. This technique would be useful for dye industries consuming water in large quantities. The partial crystallization technique for recovery and reuse of water from dye effluent will be useful in minimizing the discharge of wastewater and hence would be helpful in protecting the environment.

Conflicts of Interest

Authors declare no conflict of interest.

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