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Effect of the pH of Emulsion on Ultrafiltration of Oil Products and Nonionic Surfactants

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Abstract—The structure and properties of a water–oil emulsion have been studied. The ultrafiltration of the water–oil emulsion has been performed with the use of spiral wound and hollow fiber membranes to separate the emulsion into a filtrate and a concentrate. The effect of pH on the following performance characteristics of the ultrafiltration process has been studied: the efficiency and the degree of separation of oil products and nonionic surfactants. It was found that an increase in the pH value of the emulsion decreased the efficiency of membranes and the degree of separation of nonionic surfactants. It has been found that a Raifil UF membrane effectively rejects oil products from acidic emulsion and, on the contrary, an EMU 45-300 membrane is effective in an alkaline medium. This behavior has been associated with to a positive surface charge of the EMU 45-300 membrane. The maximum efficiencies and degrees of separation of oil products and nonionic surfactants from emulsions with the use of the Raifil UF ultrafiltration membrane and the EMU 45-300 membrane have been attained in the pH ranges from 2.1 to 2.9 and from 2.2 to 2.5, respectively. After ultrafiltration, the size of particles in the filtrate increased by a factor of about 18 due to the coalescence of oil particles in the near-membrane layer because of polarization effects. The increase in the particle size of the dispersed phase in the filtrate can also be explained by a positive surface charge of polysulfonamide membranes.

Keywords: oil–water emulsion, zeta potential, particle size, ultrafiltration, pH, nonionic surfactant

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INTRODUCTION

Oil products occur in wastewater in different states [1]: unemulsified (film on water surface), coarsely emulsified (drop size, 10–10 000 μm), finely emulsified (smaller than 10 μm), and molecular dissolved states. The removal of emulsified oil is the main problem in the treatment of wastewater containing petroleum products. The treatment is complicated because of high stability of these systems caused by the action of surface-active substances and the formation of elastic protective layers or the presence of electrolytes and an increase in the stabilizing effect of the electrical double layer.

Membrane techniques, which exhibit high separating ability, are the most effective methods for the separation of water–oil emulsions. The process of ultrafiltration is primarily used for the separation of emulsions [2–10]. The commonly used membrane units contain flat, tubular, spiral wound, and hollow fiber elements.

Many factors, such as feed fluid temperature, operating pressure, concentration and particle size of a substance to be separated, size and amount of membrane pores, and membrane surface properties, affect the process of the membrane separation of water–oil emulsions. The effects of the above process parameters on the ultrafiltration separation of water–oil emulsions were considered previously [11, 12]. The pH value of the feed liquid also influences the membrane separation process.

Thus, it was found that the ζ potential is related to the pH of emulsion by the Stern adsorption isotherm (i.e., the higher the pH, the greater the charge in absolute value) [13, 14]. In this case, the ζ potential does not depend on the electrolyte present in solution [13]. The ζ potential is also independent of the nature of oil, and it lies in the range from –50 to –60 mV. The negative charge on the droplet surface can be explained in terms of Koehn's rule [15], which states that of two phases in contact, the one with a smaller dielectric constant becomes negatively charged: the dielectric constants of water and oil (petroleum) are 81 and ~2.1, respectively.

The aim of this work was to determine the optimum values of pH in water–oil emulsions at which the maximum efficiency and the degree of separation of oil products and nonionic surfactants are reached in ultrafiltration processes with spiral wound and hollow fiber membranes.