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Experimental study on treatment of electroplating wastewater by nanofiltration

Zhi Wang *, Guangchun Liu, Zhifeng Fan, Xingtao Yang, Jixiao Wang, Shichang Wang

Chemical Engineering Research Center, School of Chemical Engineering and Technology, State Key Laboratory of Chemical Engineering (Tianjin University), Tianjin University, Tianjin 300072, PR China

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Abstract

Nanofiltration (NF) was investigated for the treatment of an electroplating rinse wastewater containing Cu and Cr. Three NF membranes, DL, DK, and NTR-7450, were used in the experiment. Effects of pressure, temperature, and feed pH on membrane performance were investigated. With the rise of pressure, flux decline with time for DL and DK membranes was obvious. Flux of NTR-7450 membrane was stable at different pressure in the experiment. With the increase of pressure, the Cr and Cu rejections of three NF membranes increased slightly. With the rise of temperature, the permeate flux increased and rejections of Cr and Cu did not change obviously in the scope of this experiment. The change of flux with feed pH was not great generally. The permeate flux was minimum around the isoelectric points of the membranes. The Cr and Cu rejections for the feed with pH more than 7 were greater than that for the feed with pH less than 7. In the latter stage of the NF concentration process, flux decline behaviors of membranes were obvious. Stability investigation results showed that DK membrane had better stability in the raw electroplating wastewater with pH 2.32 than DL membrane.

Keywords: Nanofiltration (NF); Wastewater treatment; Electroplating wastewater

1. Introduction

One of the critical pollution problems arising from the electroplating industry is the generation of rinse water for electroplated parts. The rinse water contains a certain amount of heavy metals, which are major causes of water and soil pollution. Heavy metals pose a serious risk to humans, animals, and the environments. Therefore, it is necessary to treat electroplating rinse wastewater prior to its discharge.

Due to the increasingly stringent environmental legislation, treatment of wastewater laden with heavy metals has received considerable attention. Different treatment techniques such as chemical precipitation, coagulation–flocculation, flotation, ion exchange, and membrane filtration have been tried to treat the wastewater [1]. Although chemical precipitation and coagulation–flocculation have been widely used to treat electroplating wastewater, their drawbacks like excessive chemicals consumption, sludge production, and impossibility of directly reusing heavy metals are obvious.

Due to their high efficiency and convenient operation, ultrafiltration (UF) [2,3], and reverse osmosis (RO) [4,5] membrane processes have been increasingly used in the treatment of wastewater laden with heavy metals. If the heavy metals in wastewater are separated by membrane, both the filtered water and the collected heavy metals can be reused directly [6,7]. Compared with RO, NF process has lower energy consumption for the loose structures of NF membranes. There are several studies utilizing NF as tools for removal of heavy metals like Ni, Cu, and Cd, which are generally multivalent ions [8–10]. These results show that NF is a promising technology for the treatment of heavy metal wastewater. However, NF is less intensively investigated than UF and RO for the removal of heavy metal [1]. Limited studies have been done using NF, mostly for simulated electroplating wastewater. Further studies are needed to select the commercial NF membranes applicable for the treatment of real electroplating wastewater. In addition, just like the

* Corresponding author. Tel.: +86 22 27892155; fax: +86 22 27404496.
E-mail address: wangzhi@tju.edu.cn (Z. Wang).

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Table 1
Composition of the raw electroplating wastewater

Item	Concentration (mg/L)	Item	Concentration (mg/L)
K^+	1.868	Na^+	13.785
Ca^{2+}	15.96	Mg^{2+}	0.150
Zn^{2+}	0.6135	NH_4^+	33.95
Mn^{2+}	0.061	Cu^{2+}	11.780
Ni^{2+}	0.81	Cr^{3+}/Cr^{6+}	17.09
SO_4^{2-}	415.8	NO_3^-	100.8
Cl^-	27.5	HCO_3^-	–
F^-	232.5	SiO_2	1.78

permeability and selectivity, stability of NF membranes is also important in the treatment of electroplating wastewater. However, the stability investigation of NF membranes is always neglected. Therefore, comprehensive studies on the performance of NF in the treatment of real electroplating wastewater are necessary for the actual full-scale industrial implementation.

In this paper, NF process was studied for the treatment of a real rinse wastewater. Three kinds of commercial NF membranes, DL, DK, and NTR-7450, were used in the experiment. Effects of pressure, temperature, and feed pH on membrane performance were investigated. In addition, NF concentration experiments were carried out, and stability of NF membranes in the electroplating wastewater was examined.

2. Experimental

2.1. Wastewater and membranes

All the wastewater used in this work was from an actual electroplating plant. Except for the NF concentration experiment, the same batch of wastewater was used in the experiments and the composition of this batch could be seen in Table 1. It can be seen from this table that the wastewater has a higher Cu and Cr content than other heavy metals. Therefore, the removal of Cu and Cr from wastewater through NF was investigated in this work. The pH value of the raw wastewater was 2.32. In the experiments to investigate the feed pH effect and the membrane stability, hydrochloric acid (0.1 M), and sodium hydroxide (0.1 M) aqueous solutions were used to adjust the wastewater pH. The feed of NF concentration experiment was another batch of wastewater. Its Cu and Cr concentration was 16.24 and 15.15 mg/L, respectively.

Three kinds of NF membranes were used in the experiment. The detailed characteristics of these membranes are shown in Table 2. NF membranes were immersed in pure water for 10 h before use. At the beginning of all the experiments, NF membranes were precompacted with pure water under the pressure of 2.4 MPa to obtain stable membrane structure.

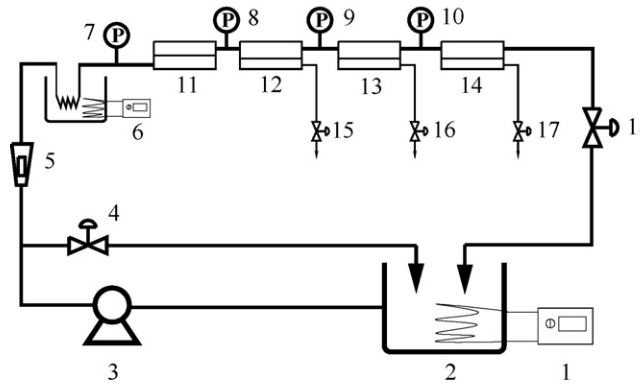

Fig. 1. Schematic diagram of the NF experimental set-up. 1 and 6, temperature adjustment system; 2, feed tank; 3, pump; 4, 15–18 valve; 5, rotermeter; 7–10, pressure gauge; 11, MF cell; 12–14, NF cell.

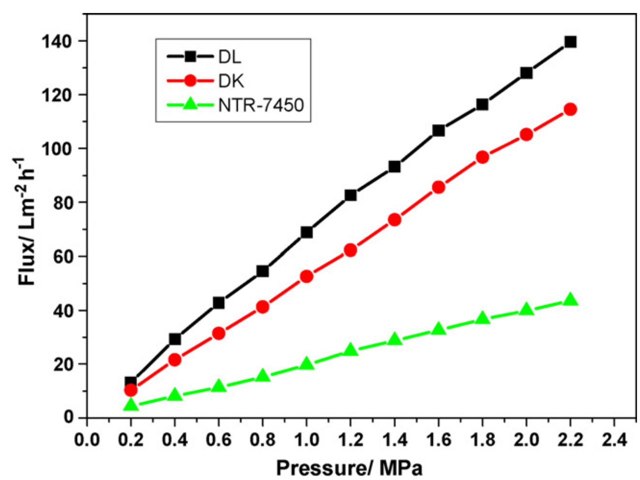

Fig. 2. Effect of pressure on pure water fluxes of NF membranes.

2.2. Experimental set-up and methods

The experimental set-up of electroplating wastewater treatment is illustrated in Fig. 1, which contains three same NF cross-flow membrane cells. Each of the cells has an effective filtration area of 19.5 cm^2. The purpose to use three NF cells in sequence is to verify the test results of membrane flux and rejection. Pressure and feed concentration in the three cells were somewhat different, but the differences were not great. Thus, the data of the first NF cell (12) were used to calculate the membrane flux and rejection, and the data of the following two NF cells (13 and 14) were used to verify the data of the first NF cell.

Table 2
Characteristics of NF membranes used in the experiment

NF membrane	MWCO	Charge	Temperature (max) (°C)	pH tolerance	Manufacturer
DL	150–300	Negative	50	2–11	Osmonics
DK	150–300	Negative	50	2–11	Osmonics
NTR-7450	200	Negative	40	2–14	Hydronautics