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# Investigation of optimal mode parameters of nanofiltration separation process

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## Abstract

The main operating parameters of the process of nanofiltration separation are investigated in the work: pressure, speed of the circulation flow and height of the pressure chamber of the membrane module to determine their optimal values. Theoretical and experimental studies have shown that relatively small pressure chamber with a height of 0.2–0.4 mm is optimal for ensuring laminar flow of deionized water in the pressure chamber of the membrane device, while the optimal range of transmembrane pressure and tangential flow speed is 5 bar and 5 m/s, respectively, which ensures optimization of the nanofiltration process due to increasing the degree of separation and reducing energy consumption.

**Keywords:** nanofiltration, membrane, pressure, pressure chamber.

## Introduction

The United Nations (UN) has set Goal 6, “Ensure access to and sustainable management of water and sanitation for all” through the Sustainable Development Goals (SDG) initiative [1-2]. By 2030, international cooperation with developing countries in water and sanitation-related activities and programmes should be enhanced, including effective water resource management, wastewater treatment, desalination, recycling and reuse technologies [3-4]. Nanofiltration is a technology that can effectively remove solutes with a size of approximately 1 nm, organic compounds with a molecular weight of 200 to 1000 Daltons, and multivalent metal ions from liquids.

The aim of the study is to investigate the optimal operating parameters of the nanofiltration separation process for industrial volume filtration streams. The study included experiments with various combinations of pressure, circulation flow rate, and membrane unit pressure chamber height to determine the optimal values.

Each process requires individual adjustment of these parameters to improve separation efficiency, increase productivity, and reduce energy consumption.

## Experiment

Experimental studies were conducted on a laboratory membrane module operating on the tangential principle created at the institute under pressure conditions of 5 to 12 bar. To determine the permeate flux, water with a turbidity of FTU-0.03 in Formazin units, 5 mg/l demineralization and $5\times10^{-4}$ cm/m electrical conductivity was used. To study the hydrodynamic characteristics of the fluid flow, the Reynolds number was calculated, which was determined for a fluid moving at different speeds (v, m/s) and a cell of geometry, the width of which is 12 mm, length 32 mm, height 0.1 mm; 0.2 mm; 0.4 mm; 0.6 mm; 1 mm. For testing the performance of the membrane module, nanofiltration aromatic polyamide membranes with selectivities of 80%, 90% and 96% for 0.25% NaCl, 0.2% $MgSO_4$ were used. To determine the optimal separation conditions, the flow rate was controlled to maintain a laminar range [5-6].

## Results and judgment

Theoretical calculations have determined the ranges of Reynolds constants at which the laminar mode of fluid movement is achieved in the pressure chamber of the membrane apparatus. Based on the analysis of the obtained results, it was determined that to ensure the laminar flow of deionized water in the pressure chamber of the membrane apparatus ($Re<2000$), the optimal pressure chamber is a pressure chamber with relatively low heights of 0.1 mm; 0.2 mm and 0.4 mm. A pressure chamber with a large cross-sectional area requires more energy to maintain the proper flow of fluid in the device, which significantly reduces the overall energy efficiency of the system. At the same time, the large height of the pressure chamber leads to uneven distribution of the fluid flow during low flow velocity, which negatively affects the efficiency of the separation process. Since nanofiltration occurs in the high pressure range, energy consumption increases significantly to maintain the proper fluid flow. Therefore, pressure determines the aspects of fluid velocity, the amount of fluid passing through the system per unit time, and the optimization of process parameters. Experiments conducted at pressures of 5 to 12 bar have shown that at a pressure of 5 bar, the permeate flow reaches a steady state at the initial stage of the filtration process. Nanofiltration at pressures of 5 to 12 bar has shown increases the permeate flow, but reduces the selectivity of the membrane, therefore, the efficiency of optimizing the baromembrane process at low pressure is much higher than at high pressures.

It should also be noted that using a membrane apparatus with a high-pressure chamber for nanofiltration of industrial volumetric filtration flows requires more powerful pumps and increased energy consumption. For sterile water purification by nanofiltration in laminar flow mode, a membrane apparatus with a high-pressure chamber size of 0.2 mm was used, equipped with polyamide membranes with selectivity of 80%, 90%, and 96%. Nanofiltration was performed at a pressure of 5 bar.

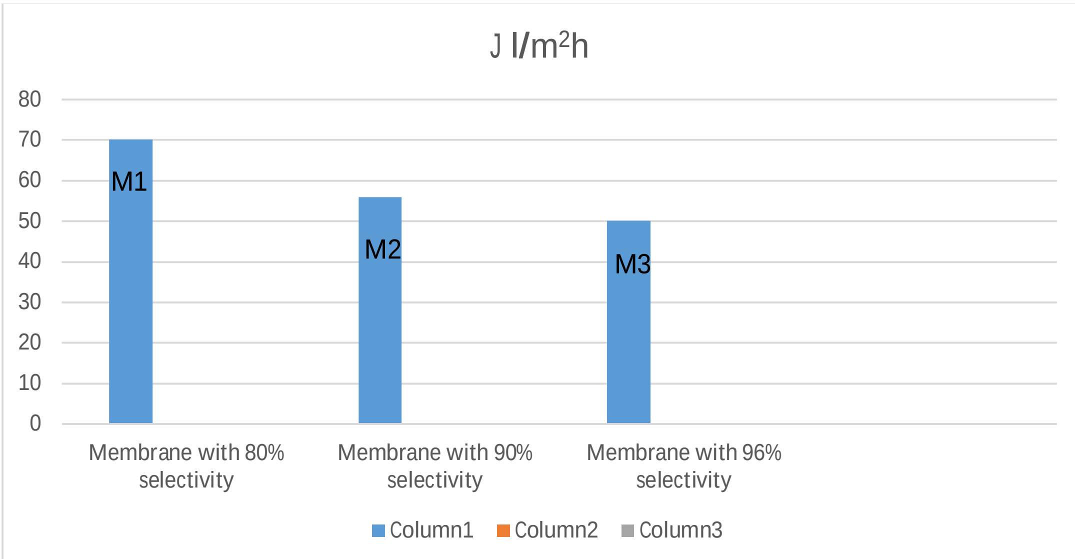


Fig. 1. Performance comparison chart

To prepare 1,000 liters of process water, the M1 membrane requires 57.14 hours of filtration in a four-stage nanofiltration system, while the M2 and M3 membranes require 53. 57, and 40 hours of filtration, respectively. Filtration time depends on the type of membrane used. The selectivity of the nanofiltration membrane directly affects filtration time: the higher the selectivity, the slower the filtration time and the lower its throughput. When designing nanofiltration systems, there is a trade-off between filtration rate and separation quality. To increase filtration time, more selective membranes can be used or the pressure can be increased to maintain flow [7].

## Conclusion

Based on the conducted theoretical and experimental studies, we can conclude that by adjusting the main operating parameters: working pressure, tangential flow rate and pressure chamber height of the membrane unit, it is possible to optimize the operating mode parameters of nanofiltration, which improves the separation efficiency, purified water quality, unit productivity and reduces operating costs, using a membrane with 80%, 90%, 96% selectivity according to 0.25% NaCl, 0.2% $MgSO_4$, under laminar flow conditions.

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# ნანოფილტრაციული გაყოფის პროცესის ოპტიმალური რეჟიმული პარამეტრების კვლევა

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საქართველოს ტექნიკური უნივერსიტეტის მემბრანული ტექნოლოგიების საინჟინრო ინსტიტუტი

**რეზიუმე**

ნაშრომში შესწავლილი იქნა ნანოფილტრაციული გაყოფის პროცესის ძირითადი ოპერაციული პარამეტრები: წნევა, საცირკულაციო ნაკადის სიჩქარე და მემბრანული დანადგარის სადაწნეო საკნის სიმაღლე მათი ოპტიმალური მნიშვნელობების დასადგენად. თეორიულმა და ექსპერიმენტულმა კვლევებმა აჩვენა, რომ მემბრანული აპარატის სადაწნეო საკანში დეიონიზირებული წყლის მოძრაობის ლამინარული ნაკადის უზრუნველსაყოფად ოპტიმალურია შედარებით დაბალი სიმაღლის სადაწნეო საკნები 0,2-0,4 მმ, ხოლო ტრანსმემბრანული წნევის და ტანგენციალური ნაკადის სიჩქარის საუკეთესო დიაპაზონია შესაბამისად 5 ბარი და 5 მ/წმ, რომლებიც უზრუნველყოფენ ნანოფილტრაციული პროცესის ოპტიმიზაციას გაყოფის ეფექტურობის ხარისხის ამაღლებით და ენერგომოხმარების შემცირებით.

**საკვანძო სიტყვები**: ნანოფილტრაცია, მემბრანა, წნევა, სადაწნეო საკანი