RUSSIAN ACADEMY OF SCIENCES

SECTION “MEMBRANES AND MEMBRANE TECHNOLOGIES” OF D.I. MENDELEEV RUSSIAN CHEMICAL SOCIETY

RUSSIAN FOUNDATION FOR BASIC RESEARCH

RAS SCIENTIFIC COUNCIL ON PHYSICAL CHEMISTRY

RUSSIAN MEMBRANE NETWORK

KUBAN STATE UNIVERSITY

«MEMBRANE TECHNOLOGY» INNOVATION ENTERPRISE

N.S. KURNAKOV INSTITUTE OF GENERAL AND INORGANIC CHEMISTRY RAS

INTERNATIONAL CONFERENCE

Ion transport in organic and inorganic membranes

Conference Proceedings

2 - 7 June 2013

Krasnodar 2013

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DETERMINATION OF NANOFILTRATED MEMBRANE MASS TRANSFER RESISTANCE AFTER SEPARATION OF WHEY

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Introduction

Nanofiltration is a baromembrane process which is widely used in various industries, particularly in the food industry. If to compare it with reverse osmosis it is characterized by high performance, lower power consumption and, moreover, it allows separating monovalent ions of polyvalent and macromolecular compounds [1]. Such advantage is the main reason for development of new whey processing technologies by using nanofiltration [2, 3]. While concentrating solids partial demineralization of whey, first of all, reduces the amount of moisture evaporated in a vacuum evaporator, and with its further processing improves the crystallization of lactose [4], which, in turn, reduces energy consumption during its spray drying [5], and secondly, treating this whey on electrodialysis for deep demineralization is recommended [6], as it increases the electrical conductivity and decreases the liquid volume which requires a smaller pump that positively affects the power consumption of such treatment [7].

However, fouling of membrane during separation of liquid medias is unavoidable, this leads to growing of membrane mass transfer resistance and, consequently, to decreasing its effectiveness. The reason for this, in most cases, is the concentration polarization, adsorption, gelling, sealing or blocking of pores [8]. There is no data in the scientific literature concerning mass transfer resistance of nanofiltrated membrane OPMN-P after separation of whey, which requires a special research.

Therefore, the aim of this paper was to determine the value of mass transfer resistance of nanofiltrated membrane OPMN-P after separation of whey because this is an important indicator in assessing the level of membrane fouling.

Experiments

Pretreatment of the new membrane OPMN-P (JSC STC "Vladipor", Russia) was by filtering distilled water at the operating pressure of 2.5 MPa to adjust a stable performance. Experiments were conducted on a laboratory unit. The effective membrane area was $4{,}3 \cdot 10^{-3}$ m^2.

Results and Discussion

The distilled water flux of the new membrane at a pressure of 2.5 MPa was 190.24 $dm^3/(m^2h)$. Dynamic viscosity of water at 20°C was 1004 10^{-6} Pa s. Resistance membrane R_m, was calculated, which was 4,7 $10^{13} m^{-1}$for membrane OPMN-P under the mention conditions.

It was found out that whey flux of the new membrane was lower; this can be explained by sorption of whey components and by active formation of dynamic membrane on it. After reaching a concentration factor value of 1.25 the flux started to decrease more slowly due to the established dynamic equilibrium in the system. After the experiment the unit was filled by distilled water and was left for 10 minutes with mixer on. The distilled water was refilled and the flux volume was determined. It was around 30.44 $dm^3/(m^2h)$ under those conditions. This value was slightly lower than the initial flux while whey separation. General resistance, R_t, and mass transfer resistance, R_f, of adsorbed components of whey on membrane were calculated. Their values were $R_t = 29{,}5 \cdot 10^{13}$ m^{-1}, $R_f = 24{,}7 \cdot 10^{13}$ m^{-1}. As we can see, whey components had almost 5 times more resistance than membrane. Then this membrane was removed and washed, the surface was cleaned manually under running distilled water, and flux was tested again, on both distilled water and whey. Those procedures were repeated twice after which the active layer of membrane was damaged. The data are presented in Table. 1.

Based on the data achieved, we see that the flux of nanofiltrated membranes was considerably restored after mechanical cleaning. Obviously, most of the contaminants are adsorbed on the membrane surface and only a small portion enters into the pores. However, this assumption is not confirmed experimentally. During whey separation on the washed membrane we noticed that the flux was larger. It is obvious that the new membrane has a certain surface charge which leads to intense absorption of the dissolved components which in turn creates significant resistance of mass transfer. By mechanical cleaning we washed the fouling layer that was not in direct contact with the membrane surface; that affects the redistribution of the membrane surface charge and the subsequent intensity of the whey separation adsorption process. However, to confirm the above additional studies are needed to be conducted.

Table 1. Specific Membrane Capacity And Mass Transfer Resistance Values

	J, $dm^3/(m^2\ h)$	R_t, m^{-1}	R_f, m^{-1}
New membrane	190,24	4,7·1013	0
After nanofiltration of whey	30,44	29,4·1013	24,7·1013
After nanofiltration of whey + mechanical cleaning	170,83	5,2·1013	0,5·1013
After 2 cycles of nanofiltration of whey + 2 cycles of mechanical cleaning	139,51	6,4·1013	1,7·1013
After 3 cycles of nanofiltration of whey + 3 cycles of mechanical cleaing	149,47*	6,0·1013	1,3·1013

*active layer of membrane was damaged

Repeated washing showed that R_f was increased almost three times (Table 1), although the flux of separating whey remained at the same level. The authors [9] also noticed the increase in mass transfer resistance when ultrafiltrating coconut water by number of repeated experiments. Therefore, an important step in the developing industrial technologies is a study of nanofiltrated membranes regeneration process by chemical reagents, for instance.

Summary

It was found out that mass transfer resistance of the new nanofiltrated membrane OPMN-P (JSC STC "Vladipor, Russia") at the pressure of 2.5 MPa is $R_m = 4{,}7 \cdot 10^{13}\ m^{-1}$, however, this figure rises to 6.25 times after whey separation and the overall mass transfer resistance reaches $Rt = 29{,}4 \cdot 10^{13}\ m^{-1}$. Mechanical cleaning of the membrane surface, though, restores the flux but leads to rapid membrane damage. The study of nanofiltrated membranes regeneration process after whey separation using chemical reagents is promising.

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