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The Analysis of Experimental Data Obtained by Microfiltration of Natural Water

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Abstract – In the work the micro-filtration processes in fresh natural waters are considered. The effect of the variation of the height of the forcing chamber on the membrane flux of the pure wateras well as the problem of extrapolation of the relationship between various turbidity of model solutions and productivities were studied. By means of experimental curve of mentioned relationshipthe analytical view at extrapolation curve was established. It has been found that at baromembrane filtration the various turbidity of the model solutions determines the variation of asymptotic values offlux of the pure water. The efficient regulation andfurther prediction is possible in the conditions of the variation of the height of forcing chamber at equal energetic consumption.

By experimental results it was established that in the course of baromembrane filtration in the range of various turbidity from 1 to 40 NTU the extrapolation curve of the relationship between asymptotic values of model solutions and flux of the pure water represent square paraboloid. Reserch process was carried out on laboratory scale. Flux of the pure water was determined end experimentally at laboratory plant Turbidity of model solutions was by measured turbidity measurer.

Keywords – Membrane; Microfiltration; Flux Of The Pure Water (Specific Productivity); Turbidity.

I. INTRODUCTION

Provision of the population by ecologically pure products and fresh water is tightly associated with the elaboration and introduction of new,current technologies. From this viewpoint the importance of membrane technology was sharply increased within recent years since membrane technology and membrane processes allow to purify the sewage from all kinds of contamination at coloidal as well as at low-molecular levels and to elaborate the wastless technologies. To obtain the high-quality fresh water from the mineral water the elaboration of stably operating, highly productive corresponding construction of membrane apparatus by such hydrodynamic regime at which the deposit doesn't formed on membrane surface which hinders the process of micro- and ultrafiltrational membrane apparatus andin the course of their operation. On the membrane surface on the walls of their pores the sorbing of various compounds is proceeded, contaminating particles are precipitated, hydraulic resistance of membrane apparatus increases and maincharacteristics of the separation process - membrane productivity and selectivity reduces.

To increase flux of the pure water of membrane apparatus, in which the created construction of forcing chamber and hydrodynamic and mass transfer processes in it must provide efficiency of separation processes and high technical-economic indices. What is to say, on one side, the stream velocity mustn't exceed the critical one in the forcing chamber and, on the other hand, the plant must operate at the low pressure.

The goal of the work involves the study of the relationship between various turbidity of model solutions and flux of the pure water and establishing of analytical view of extrapolation curve by means of experimental one which allows the efficient regulation of the values of flux of the pure waterand further prediction in the conditions of the variation of the height of the forcing chamber.

The motion of the liquid separated by the membrane in the channel of the forcing chamber, is accompanied by the drain of the part of the liquid through the filter on the wall of planar channel, causing the significant variation of the hydrodynamic parameters along the length. The intensity value of the membrane in the most cases is directly dependent on the local transmission capacity of the membrane working surface. Therefore, to describe the process of membrane separation the study of the problem of the velocities and concentrations of liquid stream in the cross- section of the forcing channel is of importance.

In the apparatus of various construction, for estimationof the processes of membrane selectivity and separation, a number of the concepts, elaborated by various authors are presented in which the different approaches are used at consideration of the mentioned problem.For example, Altena et al. and Belfort et al the several models have proposed to explain the filtration theory. The models were confirmed experimentally in the course of microfiltration processes for dead ended as well as for tangential filtration at various velocities of the stream [1-2].

In the work of Cristian R. Bouchard, Pier J. Karey, Takeshi Mattsura and S. Sourajan:"Modeling ofultrafiltration: Predictions of concentration polarization effect" the modelling of concentrational polarization at the ultrafiltrational tangencial process is considered for the channel of the rectangular cross - section at laminar flow [3]. The efficiency of the membrane apparatus, caused by the variation of the stream velocity and other parameters is shown, In the work of Aleksei Pervov:" The influence of hydrodynamic factors, membrane surface channel geometries on membrane performance and Fouling mechanisms" the experimental research is presented on the variation of the specific parameters, membrane surface properties and channel geometry [4]. In the work of Yu.I.Ditnerski and N.S.Orlov: "On the calculation of membrane forking surface using mass transfer concept" the hydrodynamic regimes of mass exchange in micro- and ultra-filtration processes were studied and various schemes of tangential filtration processes were considered [5].

To attain of our goal the experiments were planned to determine flux of the pure water by microfiltration process at the laboratory plant at various heightsof the forcingchamber and at different turbidities.

We have used the empirical approach to reveal the conditionsin the processes of baromembrane filtration the study of the relationship between various which allows the efficient regulation of the values of the flux of the pure water and further prediction in the conditions of the variation of the height of the forcing chamber.

II. EXPERIMENTAL PART.

For experiment performing the distilled water (OST-67-09-72) and the water of various turbidity (0,75 NTU; 9,95 NTU; 20,5NTU; 40,9NTU; 58,8 NTU) were used. The experimental plant is presented in Figure1.

Figure1. Laboratory experimental plant

For the test performing at the experimental plant firstly the investigated liquids of 5l amount were prepared. It was sufficient for 4hour tests at the temperature of 20^0C. The turbidity of the initial liquid was measured at the turbidity measurer TURBO 555-UR. After the setting up of the experiments the volumes of filtrate- V_{fil}- and permeate-V_{per} at taking of weredetermined after each half an of hour time interval at taking of the readings inΔt min; geometric sizes of the working unit of the forcing chamber comprises: width B=9$\times 10^{-3}$m; length L=30$\times 10^{-3}$ m; membrane area ω= B$\times L$= 270 $\times 10^{-6}$m^2. The principal calculating scheme for the membrane separation is presented in Figure 2.

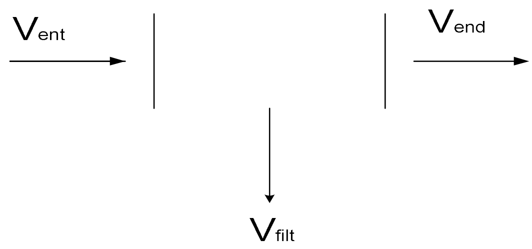

Figure 2.The principal calculating scheme for the membrane separation

For transformation of experimental results to calculate flux of the pure water the formula was used [5]:

$$J = \frac{V_{fil}}{\Delta t \times \omega_{mem}} \qquad (1)$$

Where V_{fil}- volume of experimental filtrate, taken over Δt minutes and ω_{mem}- working surface of the membrane which in this case comprises ω_{mem}= B× L= 270×10^{-6} m^2.

Flux of the pure waterat laboratory plant were studied at three values of the height H of the forcing chamber:0,6×10^{-3}m; 0,4×10^{-3}m; 0,2×10^{-3}m by the size of membrane pores 5mμ and 2 mμ. Liquid pressure comprised P= 0,5 bar and velocity v=1m/sec. The interval of the readings wasΔt=60 sec.

Along with it for the natural waters of various turbidity: 0,75 NTU; 9,95 NTU; 20,5NTU; 40,9NTU and 58,8 NTU flux of the pure waterhave been studied at the pressure: P=1 bar, velocity v=0,5m/sec on the membrane of 2 mμ , at the temperatureof 20^0C. In the course of the experiments in the vessel of initial liquid the mixer was placed. Time interval comprised Δt=180sec at the readings of the data of V_{fil}, obtained experimentally.

III. Results and discussion

3.1 Effect of the height of the forcing chamber on flux the of the pure water.

Table 1. The values of experimentally obtained flux of thepure waters in the distilled water by time at the various heights of the forcing chamber and at various sizes of membrane pore.

Chamber height H (10^{-3}m)	Specific productivity by time J (L/(h ×m^2))							
	t=0,5 (h)	t=l,0 (h)	t=1,5 (h)	t=2,0 (h)	t=2,5 (h)	t=3,0 (h)	t=3,5 (h)	t=4,0 (h)
	Membrane pore size 5 mμ							
0,6	4888	4000	3444	3000	2666	2333	2111	2000
0,4	6000	4800	4000	3444	3022	2733	2444	2333
0,2	6666	5444	4556	3999	3667	3333	3111	2888
	Membrane pore size2mμ							
0,6	1355	844	644	511	444	400	378	355
0,4	1778	1167	888	687	555	467	433	422
0,2	2111	1422	1066	844	667	577	533	488

The variation of the experimental results forflux of the pure waterby time on the membrane of 5 mμ Table1 are presented graphically in Figure 3.

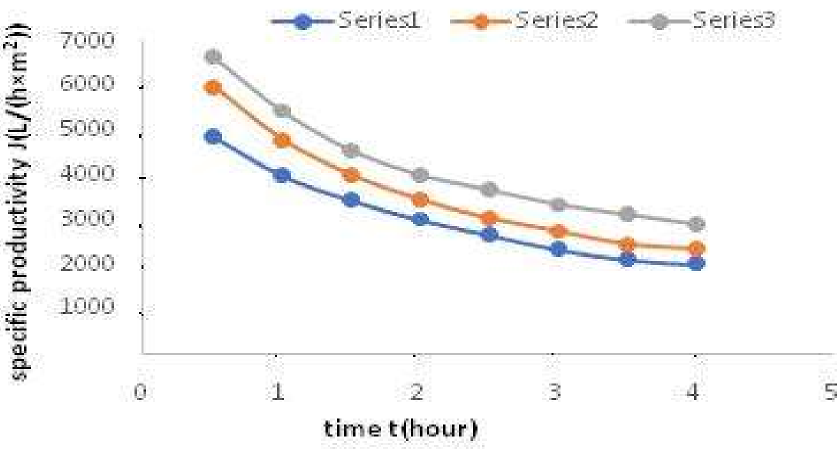

Figure 3. Experimental results for the distilled water. Graphical presentation of the values of flux of the pure water by time for the membrane of size5 mμ: series 1-the height of forcing chamber H=0,6× 10^{-3}m; series 2-the height of forcing chamber H=0,4× 10^{-3}m; series 3-the height of forcing chamber H=0,2× 10^{-3}m; From the Figure3 it is evident that the relatively high drop of the values of flux of the pure water in the results of the experiments on the membranes whit the pore size 5 mμ up to 2 hours from the experiments beginning than it was after period of the time at reducing of the height of the forcing chamber the values of flux of the pure water are growing more (more and more higher) .Experimental results for the membrane of 2mμ (Table1) are presented graphically in Figure 4.

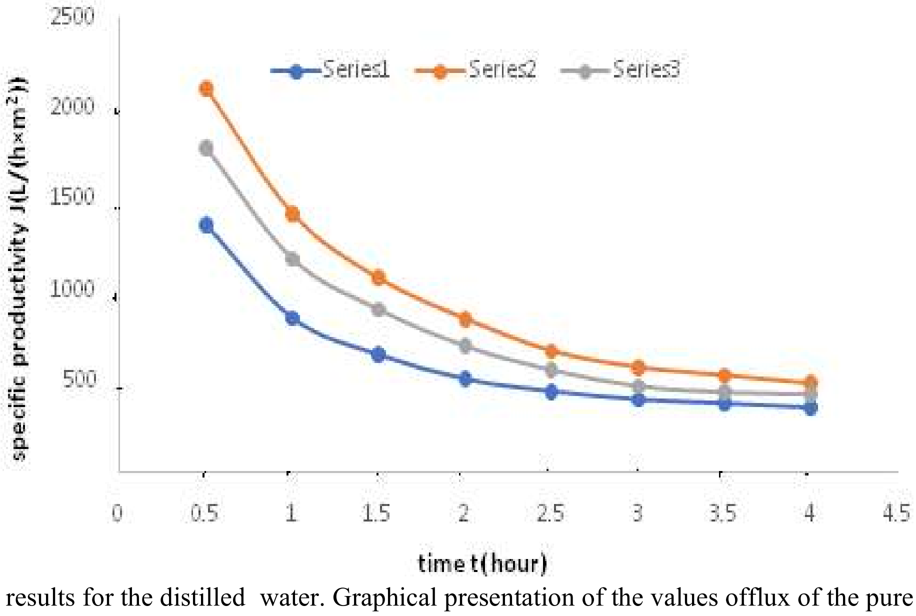

Figure 4. Experimental results for the distilled water. Graphical presentation of the values offlux of the pure water by time for the membrane of size 2mμ: series 1-the height of forcing chamber H=0,6× 10^{-3}m; series 2-the height of forcing chamber H=0,4× 10^{-3}m; series 3-the height of forcing chamber H=0,2× 10^{-3}m;

Here, similarly to Figure 3. the values of the flux of the pure waters are characterized by sufficiently high drop in the test course up to 2 hours and in the time further period the drop is relatively less. It should by noted that flux of the pure water increase at decrease the height of the forcing chamber.

Table 2. Experimental values of flux of the pure watersat various heights of chamber by the data of 4 hour tests.

Height of forking chamber H (10^{-3}m)	Specific productivity J (L/(h.×m^2))
Membrane pore size 5mμ	
0,6	2000
0,4	2333
0,2	2888
Membrane pore size 2mμ	
0,6	355
0,4	422
0,2	388

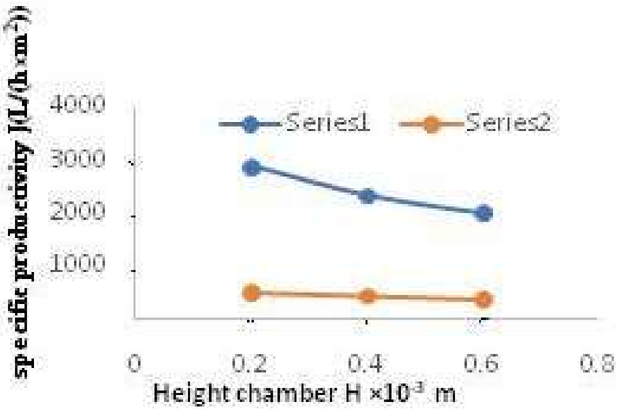

Figure5. Experimental results for the distilled water. Relationship between flux of the pure waterand chamber heights for the data of 4hour experiments. Series 1 - membrane of 5mμ; Series 2 - membrane of 2mμ.

As is evident from Figure 5, the effect of the height is seen more obviously for the membrane of 5mμ size than for the membrane of 2mμ size.

On the basis of the analysis of obtained results the following conclusion can be made: the lower is the height of the forcing chamber the higher is the membrane flux of the pure water. This is determined by the minor increase of the velocity at membrane surface since the velocity distribution is parabolic in the forcing chamber and for the higher chamber the parabola is less pointed and in the case of low height is more pointed. Therefore, at the membrane surface the minor increase of liquid velocity is observed causing the enhance of the productivity.

3.2. Experiments on natural water of various turbidity

Table 3. Experimental values of flux of the pure waterin the course of micro- filtration of natural water of various turbidity.

Initial turbidity NTU	Chamber pressure P (bar)		Liquid volume V (ml)				Specific productivities J by time (L/(h×m^2))							
			At experiment beginning		At experiment end		t=0, 5	t=1	t=1, 5	t=2	t=2, 5	t=3	t=3, 5	t=4, 0
	In. P_1	Fin P_2	V_f	V_p	V_{fil}	V_p	(h)	(h)	(h)	(h)	(h)	(h)	(h)	(h)

0,75			28	800	2,4	-	2000	1288	933	700	533	533	533	533
9,95			30,5	303,5	2,35	670	1656	1111	800	622	525,2	525,2	525,2	525,2
20,5	1	0.2	12	225	2,2	575	1244	800	578	533	510	489	489	489
40,9			15	395	1,8	650	844	578	448	444	422	400	400	400
58,5			17	573	1,35	755	771	488	400	388	378	356	311	300

By the data of Table 3 at the microfiltration of natural water of various turbidity the values of flux of the pure water from the certain time, are repeated:1)in the case of turbidity the 0.75 NTU- start from t=2,5 hours and J=533 l/(h.m^2);2) at turbidity 9,95 NTU- start from t=2,5 hours and J=525,2 l/(h.m^2);3) in the case of turbidity the 20,5 NTU- start from t=3 hours and J=489 l/(h.m^2);4) in the case of turbidity the 40,9 NTU- start from t=3 hours and J=400 l/(h.m^2); in the case of turbidity the 58,5 NTU- the repeatability of the values of flux of the pure water wasn't attained over 4hours of the experiments. This is indicative of the fact that 4 hours is not enough. We term the mentioned values of the repeatability as the asymptotic values of the productivity. It means that the mentioned value is constant over a long period of the time. The experimental results on flux of the pure water by time for natural waters of various turbidity are presented in Table 3.

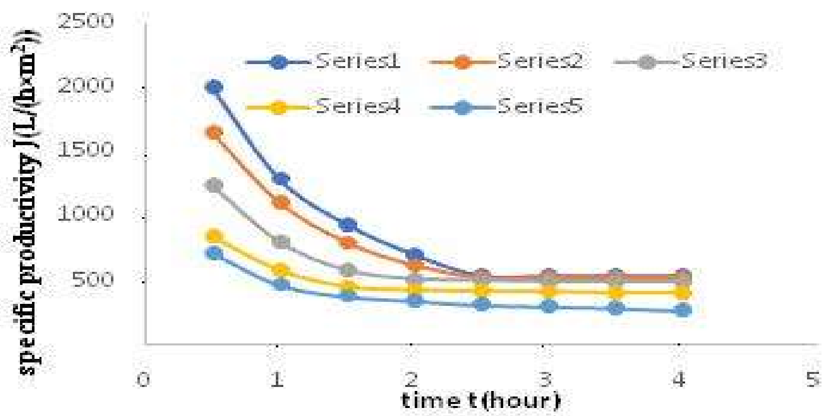

Figure 6. Variation of the productivities obtained experimentally (Table 3) by time at various turbidity: Series 1- 0.75 NTU;2) Series 2 -9,95 NTU; 3) Series 3 - 20,5 NTU; 4) Series 4-40,9 NTU; Series 5 -58,5 NTU.

As is seen from Figure 6. flux of the pure water und ergo the significant drop at all turbidities up to 1,5 hours and in the further period of the time the drop is smaller. This is indicative of the separation process fill actively the membrane pores and in the course of the further period- not so actively.

3.2.1 Construction of the extrapolation curves.

The relationship between the asymptotic values of flux of the pure waterTable4 and the turbidites from the data of Table 3 is composed, graphical presentation of which is shown in Figure 5.

Table 4. Experimentally obtained asymptotic values of flux of the pure waterat microfiltration of the natural water of various turbidity

Turbidity of initial liquid NTU	Asimptotic values of specific productivities J, L/(h×m^2)
0,75	533

9,95	525,2
20,56	489
40,9	400
60	-

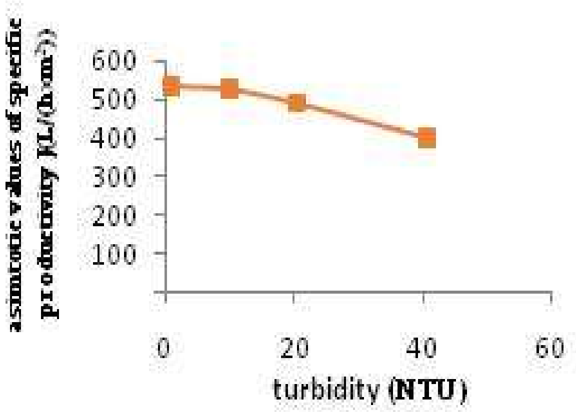

Figure 7. Experimentally obtained. graphical dependence between various turbidity and flux of the pure water.

As is seen from Figure 7, the outlin of the experimental graph is curvilinear and not linear and is similar to the second order curve. Let us present its view in the form of square trinomial [6]:

$$y = ax^2 + bx + \text{c} \qquad (1)$$

For extrapolation of the experimental curve we introduce the following values of the turbidities from the experimental curve: 10; 20; 40 (NTU) instead of X and the corresponding 525; 500; 400 (L/(h×m^2)) instead of Y. The three equations are obtained

$$\begin{aligned} 525 &= a(10)^2 + b\,10 + \text{c} \\ 489 &= a(20)^2 + b\,20 + \text{c} \qquad (2) \\ 400 &= a(40)^2 + b\,40 + \text{c} \end{aligned}$$

We have three equations with three unknown quantities and the determinants for definition of mentioned unknowns will have the view

$$\Delta = \begin{vmatrix} (10)^2 & 10 & 1 \\ (20)^2 & 20 & 1 \\ (40)^2 & 40 & 1 \end{vmatrix} = -6000 \qquad (3)$$

and

$$\Delta_1 = \begin{vmatrix} 525 & 10 & 1 \\ 500 & 20 & 1 \\ 400 & 40 & 1 \end{vmatrix} = 500; \Delta_2 = \begin{vmatrix} 100 & 525 & 1 \\ 400 & 500 & 1 \\ 1600 & 400 & 1 \end{vmatrix} = 0; \Delta_3 = \begin{vmatrix} 100 & 10 & 525 \\ 400 & 20 & 500 \\ 1600 & 40 & 400 \end{vmatrix} = -3200000 \quad (4)$$

For solving of the system of the equations (2) the Kramer formula were used [7].

The following is obtained:

$$a = \frac{\Delta_1}{\Delta} = -\frac{500}{6000} = -0{,}0833 \;, \quad b = \frac{\Delta_2}{\Delta} = -\frac{0}{6000} = 0, \text{c} = \frac{\Delta_3}{\Delta} = \frac{3200000}{6000} = \; 533{,}33 \qquad (5)$$

By introduction of mentioned values in the equation (1) the expression is obtained:

$$y = -0{,}0833x^2 + 533{,}33 \qquad (6)$$

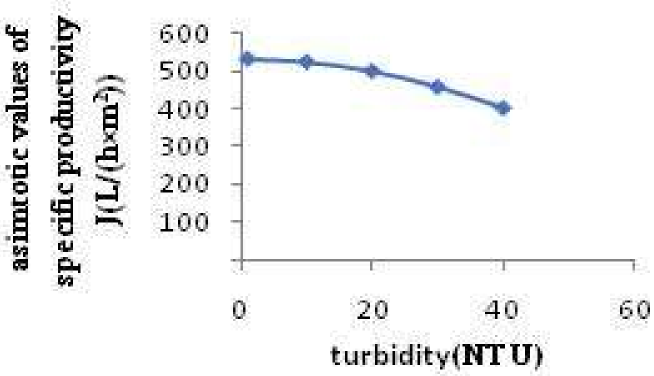

Figure 8. Extrapolation curve of the dependence between the asymptote of flux of the pure water and various turbidities.

Expression (6) presents the square parabolic.

By experimental results it was established that in the course of baromembrane filtration in the range of various turbidity from 1 to 40 NTU the extrapolation curve of the relationship between asymptotic values of model solutions and flux of the pure water represents.The curve is a branch of the parabola.

IV. Conclusions

-It has been established that the reduction of the height of the forcing chamber causes the increase of the membrane specific productivity.

- In the course of the baromembrane filtration the turbidity of the model solution determines the asymptotic value of the specific productivity

- Are established the asymptotic values of the specific productivities for the turbidity range.

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