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Both sided irradiated track membrane in local water supply

Двусторонне облученные трековые мембраны в локальном водоснабжении

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Ключевые слова: трековая мембрана; очистка воды; локальное водоснабжение; фильтрация; производительность; эффективность; спектрофотометрия; спектротурбидиметрия; гражданское строительство

Abstract. Membrane filtration is one of the main methods for individual and local water supply systems. Track-etched membranes are among the types of membranes that allow to obtain high quality purified water due to their high selectivity. Ensuring the durability of track-etched membranes is one of the topical issues on their use. Comparative research of the natural water filtration process using standard 12-μm track-etched membrane and new, more durable 20-μm irradiated on both sides was performed. Both membranes were manufactured by NPF TreM, St. Petersburg. The pore diameter of membranes was 0.20–0.205 μm, the pore density was 2.3×10^8 cm^{-2} and 1.5×10^8 cm^{-2}, respectively. The research was conducted with natural water from the pond in the park, "Malinovka" (St. Petersburg, Kosygin pr.). The filtration was run in the dead-end model. Raw water and filtrate samples were analyzed by spectrophotometry and spectroturbidimetry using KFK-3.01 photoelectrocolorimeter and SF-56 spectrophotometer. The dispersion analysis of nature water was performed by dynamic light scattering on Zetatrac laser analyze. The experimental data showed the same dependences of the productivity of dead-end filtration of pond water samples upon the volume of passed water and close values of turbidity and color in filtrate samples for both membranes. The results allowed us to recommend the 20-μm-thick membrane irradiated on both sides with a beam of argon ions having a range shorter than the film thickness for natural water purification for local water supply of individual buildings.

Аннотация. Мембранная фильтрация является одним из основных методов, применяемых в индивидуальном и маломасштабном водопользовании. С помощью трековых мембран, обладающих высокой селективностью, можно получать очищенную воду высокого качества. Но при их использовании необходимо обеспечивать прочность трековых мембран, что является актуальной проблемой. В работе проведено сравнительное изучение процесса фильтрации природной воды с использованием стандартной трековой мембраны толщиной 12 мкм и новой, более прочной, мембраны толщиной 20 мкм, облученной с обеих сторон. Обе мембраны изготовлены НПФ «Трем» (Санкт-Петербург). Диаметр пор обеих мембран составлял 0,20–0,205 мкм, плотность пор – $2,3 \times 10^8$ cm^{-2} and $1,5 \times 10^8$ cm^{-2}, соответственно. В экспериментах использовали природную воду из пруда парка «Малиновка» (Санкт-Петербург, пр. Косыгина). Фильтрацию проводили в тупиковом режиме. Образцы природной воды и фильтрата анализировали с помощью методов спектрофотометрии и спектротурбидиметрии на фотоэлектроколориметре КФК-3.01 и спектрофотометре СФ-56. Дисперсионный анализ природной воды проводили методом динамического светорассеяния на лазерном анализаторе Zetatrac. Для сравниваемых мембран были получены одинаковые зависимости производительности процесса фильтрации от объема пропущенной природной воды в тупиковом режиме, а также близкие

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значения мутности и цветности в пробах фильтрата. Полученные результаты позволили рекомендовать трековую мембрану толщиной 20 мкм, облученную с обеих сторон пучком ионов аргона с длиной пробега меньшей, чем толщина пленки, для очистки природной воды в питьевых целях.

Introduction

The problem of providing the population with pure drinking water is still remains actual for cities, towns, villages and individual consumers. The technologies of water treatment are becoming more unified for big cities. In the same time water treatment technologies for the individual consumers, small farms could strongly differ depending on the water quality in the water source, the presence of available materials (natural filtering materials, sorbents, membranes [1] or reagents),utilization of these materials, strength characteristics, and so on. Experts of water treatment and students from different universities have been engaging this problem. For example, teams of students were given different methods of water purification: membrane filtration, membrane filtration coupled with an activated carbon adsorption, ultra violet disinfection and etc [2]. The students evaluated the treatment methodologies in terms of their cost, ease-of-use, energy requirements, efficacy (on indicators of color, turbidity, and odor) and time of treatment (they also determined the time to purify the minimum amount of water needed to human a day according to the WHO recommendations).

The above implies that the membrane filtration is one of the main methods for individual water purification and local water supply. Membrane technology also dominates among other water purification technologies owing to its energy efficiency [3].

Track membranes are among the types of membranes that allow obtaining high quality purified water [4–6]. Track (nuclear) membranes are made from 12–23-μm-thick polymer films by bombarding with high-energy heavy-ion beams [7-12]. The diameter of these pores can vary in the range from 0.05 to 5 microns, depending on etching conditions.

Track Membranes are characterized by high selectivity [13, 14], but they have smaller filtration productivity than other types of membranes.

Before recommending membrane for use in the filter element, it is necessary to make certain of their strength characteristics. Therefore, durability of the membrane determines the economic efficiency of purification technology [6].

Track membrane with improved strength characteristics was obtained in [15] by realization energy-efficient variant of irradiation 20-μm-thickpolyethylene terephthalate film. Irradiation was done on both sides of a film with a beam of 53.4 MeV Ar^{+8} ions (this energy is not sufficient for the formation of a through track).

The aim of this work was to study productivity and efficiency of natural water purification process using 20-μm-thicktrack membrane produced by both side irradiation, and standard 12-μm-thick track membrane to recommend its application in the local water supply of individual buildings.

Methods and Materials

Experiments were performed on track membranes with a thickness 12 μm irradiated on one side and 20 μm irradiated on both sides (manufactured by NPF TreM, St. Petersburg). The pore diameter of membranes was 0.20–0.205 μm, the pore density was 2.3×10^8 cm^{-2} and 1.5×10^8 cm^{-2}, respectively.

The research was conducted with natural water from the pond in the park, "Malinovka" (St. Petersburg, Kosyginpr.). A preliminary defining of the relationship between the productivity of the filtration process and pressure were run with distilled water.

The filtration in this research was run in the dead-end model. In this work the cell with a filtration area of 25.5 cm^2 (manufactured by the Research-and-Production Association for Analytical Instrumentation of the RussianAcademy of Sciences, St. Petersburg) was used. The volume of this cell was 200 cm^3.

Raw water and filtrate samples were analyzed by spectrophotometry and spectroturbidimetry (KFK-3.01 photoelectrocolorimeter, Zagorskiy Optical and Mechanical Plant (ZOMZ), SF-56 spectrophotometer, OOO LOMO SPEKTR, St. Petersburg). The dispersion analysis of nature water was perfomed by dynamic light scatteringonZetatrac laser analyzer (Microtrac Inc., USA).

The electrical conductivity of the water samples was measured using a portable Multi-Range Conduction / TDS meter HI 8733N (HANNA Instruments, Germany), pH – by ionomer I-500 (OOO Aquilon, Russia).

Filtration productivity G, cm/(c*bar), was determined by the formula (1):

$$G = \frac{V}{t \cdot P \cdot S}, \quad (1)$$

where V – volume of the sample, cm^3; t – sampling time, s; P – pressure, bar; S – filtration area, sm^2.

According to the spectroturbidimetrymethod, the average particle size *d*, nm, was determined by the formula (2)

$$d = \frac{\alpha \cdot \lambda}{\pi \cdot \mu_0} \quad (2)$$

where α – relative particle size (determined by the wave exponent *n*); μ_0 –refractive index of the dispersion medium; λ – average wavelength, nm.

The average concentration ν,cm^{-3}, of the average particle size was determined by formula (3)

$$\nu = \frac{1.26 \cdot 10^{17} \cdot \tau}{(\lambda')^2 \cdot K(\alpha, m) \cdot \alpha^2} \quad (3)$$

where $\lambda' = \frac{\lambda}{\mu_0}$, in angstrom; $\tau = \frac{2.303 \cdot D}{\ell}$ (τ – turbidity; *D* –average optical density; ℓ – optical path length; m – relative refractive index; $K(\alpha, m)$ – coefficient of scattering.

Results and Discussion

While selecting an object of the research, comparison of the characteristics of water samples from the two ponds of St. Petersburg was made. Rivers and brooks flowing within the city were characterized by high pollution degree [16], so they have not been explored.

Some indicators of water samples from a pond Olginsky (st. Jacques Duclos) and pond of park Malinovka (pr. Kosygin) are presented in Table 1.

Table 1. Indicators of water quality of the pond Olginsky and thepond of park "Malinovka"

Indicator	PondOlginsky	Pondofpark "Malinovka"
Color,degrees	11	51
Turbidity, mg/L	0.6	4.0
pH	8.0	7.7
Specific electrical conductivity, μS/cm	200	590

Based on the obtained data we chose the water from the pond of park "Malinovka" because of its color and tubidity exceed the allowable values for drinking water [17].

For the sample filtered through roll filter paper, the spectrum in coordinates (lgD–lgλ) was constructed (Fig. 1).Linear region in the wavelength range 500–700 nm was selected on this spectrum. The trendline, tangent of the angle of which was equal to 3.5, was drawnfor it. This is the wave exponent value. Using the relationship between the characteristic features of the spektroturbidimetric method [18] values of the average particle size and average concentration were calculated according to the formulas (2) and (3).Since the value of wave exponential slightly exceeded its maximum (n_{max} = 3.4) average particle size and average particle concentration were evaluative: d < 140 nm, ν > 2 x 10^9 cm^{-3}.

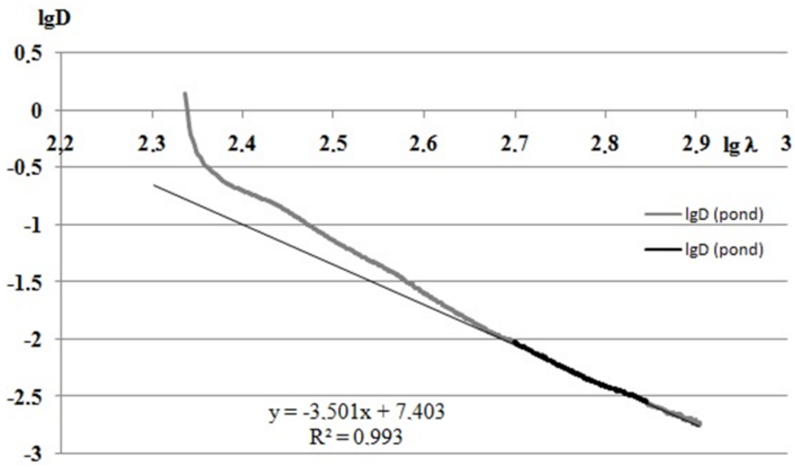

Figure 1. Dependence of the optical density logarithm on the wavelength logarithm for water sample from a pond of park Malinovka

For determining the particle size distribution dynamic light scattering method was used.The measurements were performed on the analyzer Zetatrac [19], which showed ample opportunities during the study of aggregation of polydisperse systems [20].The data were represented as scattered light intensity and particle number distributions over particle sizes.The results are shown in Figure 2 and Table 2.

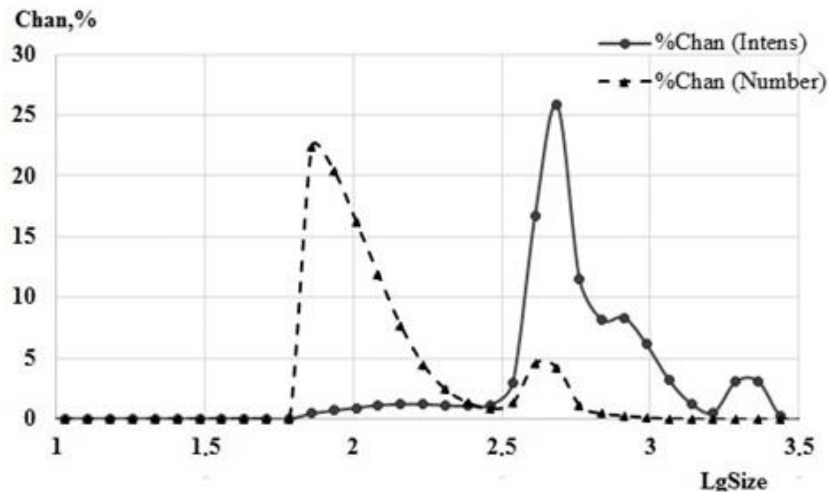

Figure 2. Scattered intensity and particle number distributions over particle sizes for water sample from a pond of park Malinovka

Table 2. Peaks Summary

Distribution	Size, nm	Vol, %	Width, nm	Loading Index
Scatteredintensity	1943	6.7	445	0.014
	459	93.3	390	
Number	410	12.5	138.4	
	86.7	87.5	59.6	

These results demonstrate that the water sample mostly contains suspended impurities smaller than 100 nm. However, a small number of larger impurities (above 400 nm) determines the main contribution to light scattering.

Microfiltration experiments were carried out in dead-end mode on the investigated membranes (12-μm-thick irradiated on one side and 20-μm-thick irradiated on both sides).

Dependences of the productivity of dead-end filtration of distilled and pond water samples through two track-etched membranesare presented at Figure 3.

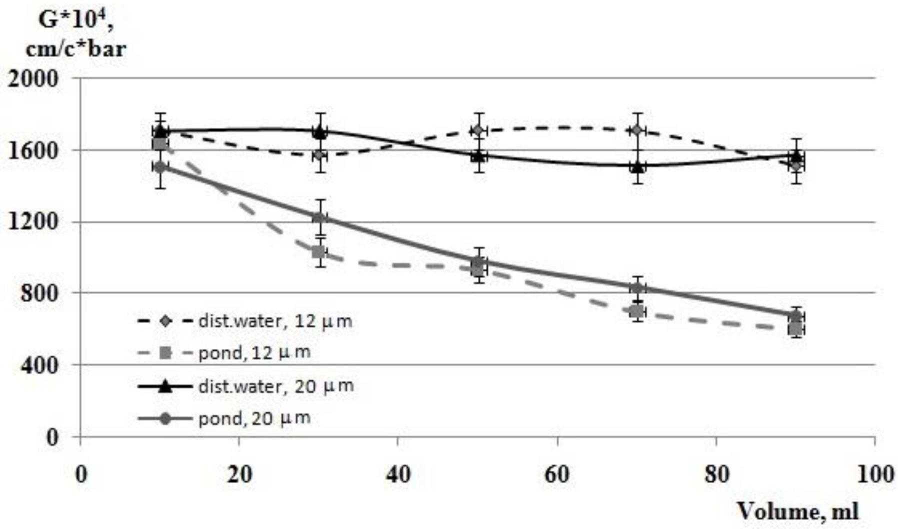

Figure 3. Dependences of the productivity of dead-end filtration of distilled and pond water samples through 12-μm-thick membrane irradiated on one side and 20-μm-thick membrane irradiated on both sides.

The results shows the same productivity properties of studied membranes, despite the high porenumber density of the 12-μm-thick membrane irradiated from one side, and almost twice-greater length of the pores in the 20-μm-thick membrane irradiated from both sides. Apparently, the transport properties of the membrane irradiated from both sides is formed with a layer of "connectivity" in the middle of the film (12–14 nm) [15].

Fig. 4 and 5 show the results of comparison of purification effectiveness (in terms of color and turbidity) of pond water by filtration in a dead-end mode on two investigated membranes.

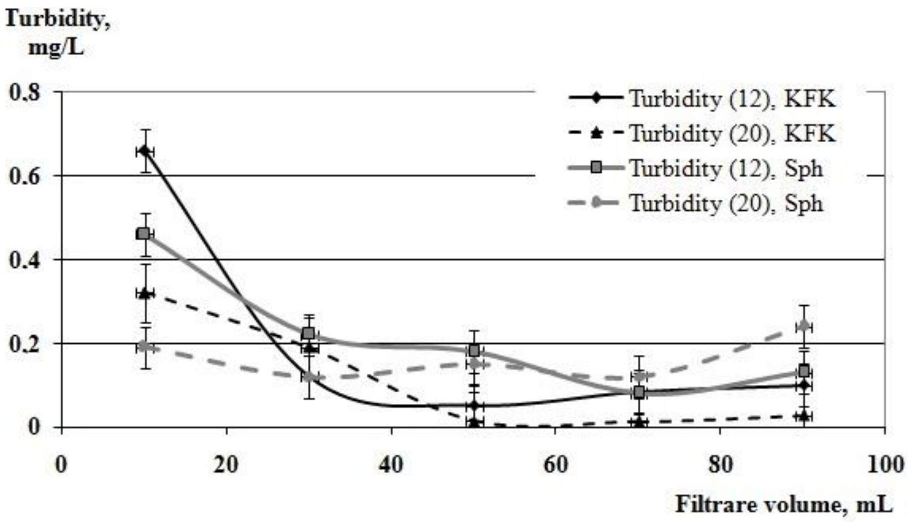

Figure 4. Dependences of turbidity in filtrate samples on filtration volume when optical density was measured using photoelectrocolorimeter (KFK) and spectrophotometer (Sph). 12–12-μm-thick membrane; 20–20-μm-thick membrane

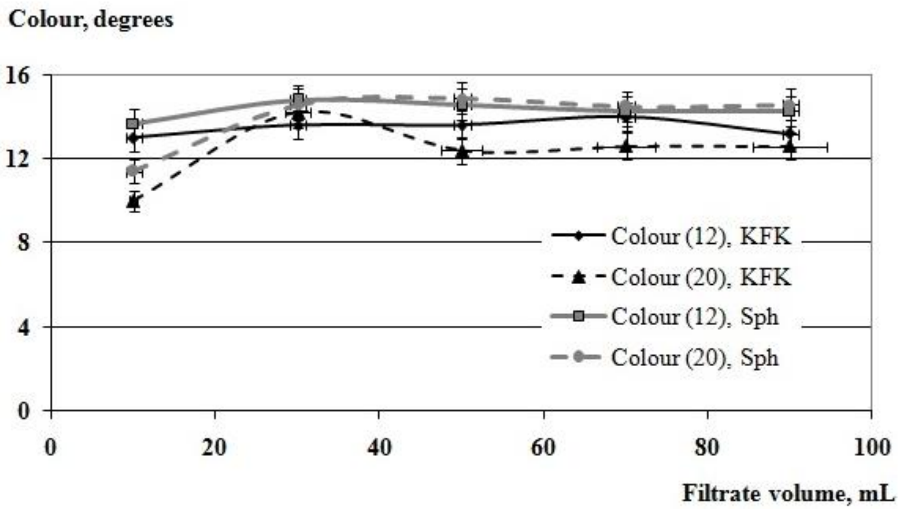

Figure 5. Dependences of colour in filtrate samples on filtration volume when optical density was measured using photoelectrocolorimeter (KFK) and spectrophotometer (Sph). 12–12-μm-thick membrane; 20–20-μm-thick membrane

Results show almost equal values of turbidity and color in the filtrate samples obtained by using the 12- and 20-μm-thick membranes. It is also seen that both membranes provide reduction of turbidity and color of water from the pond to values less than maximum permissible concentration (MAC) for drinking water (beginning from the second sample 1.3–1.4 times by color indicator, 7–10 times for turbidity).

It should be noted that theproductivity of filtration of pond water decreases slightly compared to the productivity of distilled water filtration. To reveal the cause of the drop in performance of pond water filtration process, curves for the dependence of the squared inverse productivity upon the overall filtration time were plotted. Comparison of the curves with the theoretical relationships [21] suggested the adsorption on the pore surface and pore clogging (as in [22]). This is confirmed by the relation of pore sizes (0.2 μm) and suspended impurities from pond water (Fig.2, Table 2).

Determination of suspended particle size in the filtrate samples and the size distribution by the methods used in the work was not possible, because the concentration of suspended impurities was low than sensitivity of the analyzers.

Conclusions

Comparative study of the natural water filtration process using a track membrane produced by implementing energy-efficient variant of irradiation of 20-μm-thick PET film on both sides, and a standard 12-μm-thick membrane irradiated from one side having the same pore diameter of 0.2 microns, has shown:

– similarproductivity of the filtering process;

– the same removal efficiency of suspended impurities with an average size of 90 nm and above.

The results obtained allow us to recommend the 20-μm-thick membrane obtained with a beam of argon ions having a range shorter than the film thickness for natural water purification for local water supply in such objects of civil engineering as individual buildings.

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