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TREATMENT OF WASTEWATER FROM WATER-BASED PAINTS INDUSTRY

The possibilities of treating wastewater from water-based paint industry were examined. Microfiltration was used as separation process for removing the solid particles from water. Three commercially produced paints (AQUAREX, AQUACOL MAT and FORTELUX AQUA) were tested. Experiments were performed on tubular ceramic membranes made from $\alpha\text{-Al}_2\text{O}_3$ whose mean size of pores reached 0.1 μm . The results of the experiments show that the cross-flow microfiltration is a suitable process for the treatment of wastewater from paint industry. The COD of permeates approached 2000 $\text{mg}\cdot\text{dm}^{-3}$.

Keywords: *microfiltration, wastewater, water-based paint*

NOMENCLATURE

A_m – membrane surface area (m^2),
 d_i – internal diameter of membrane (m),
 d_p – nominal pore size (m),
 J_w – permeate flux for deionised water ($\text{m}\cdot\text{s}^{-1}$),
 J_{ss} – steady state of permeate flux ($\text{m}\cdot\text{s}^{-1}$),
 L – length of membrane (m),
 ΔP – transmembrane pressure (Pa),
 R_c – filter cake resistance (m^{-1}),
 R_m – membrane resistance (m^{-1}),
 R_t – total filtration resistance (m^{-1}),
 $w_{\%}$ – total solids content (–),
 d_p – nominal pore size (m),
 μ_p – dynamic viscosity of permeate (Pa·s).

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1. INTRODUCTION

Due to the environment policy the world production of water-based paints increases unceasingly, whereas the production of solvent-paints is reduced.

Wastewater from paint industry is responsible for serious problems in wastewater treatment. They have not been compiled methodically, principally because the paints are often composed of mixtures of the compounds of unknown chemical structure. Wastewater from paint industry typically contains 2–7% dry weight of suspended solids and a soluble COD load ranging from 6.000 to 10.000 mg·dm⁻³. The waste streams are also intensively coloured. The colours may or may not be soluble depending on the type of pigments employed in the paint formulations [1].

At the moment, several methods are used for the treatment of wastewater from paint industry before its safe removal. As these waters are characterized by a high organic load and high suspended solids' content, conventional treatment methods can be successfully applied.

The most common method is the coagulation–flocculation [2], followed by gravity sedimentation. Flotation, sorption on solids as well as advanced treatment methods, i.e. ozonation, electrochemical oxidation, biological treatment, and finally membrane filtration [3], [4], are less frequently applied. Due to the dissimilarities in the composition of these wastewaters, no general rules of their treatment can be reliably established. Hence, each particular wastewater should be handled properly.

The objective of this study was to investigate the possibility of using pressure membrane processes for treating the wastewater from water-based paint industry.

2. MATERIALS

2.1. SUSPENSIONS

For separation experiments three different commercially produced water-based paints were used (made by COLORLAK, a.s., Czech Republic). They can be itemized as follows:

- AQUAREX – single-layer anticorrosive paint (signal grey),
- AQUACOL MAT – universal top coat (matt brown),
- FORTELUX AQUA – thick-layer glazing (maroon).

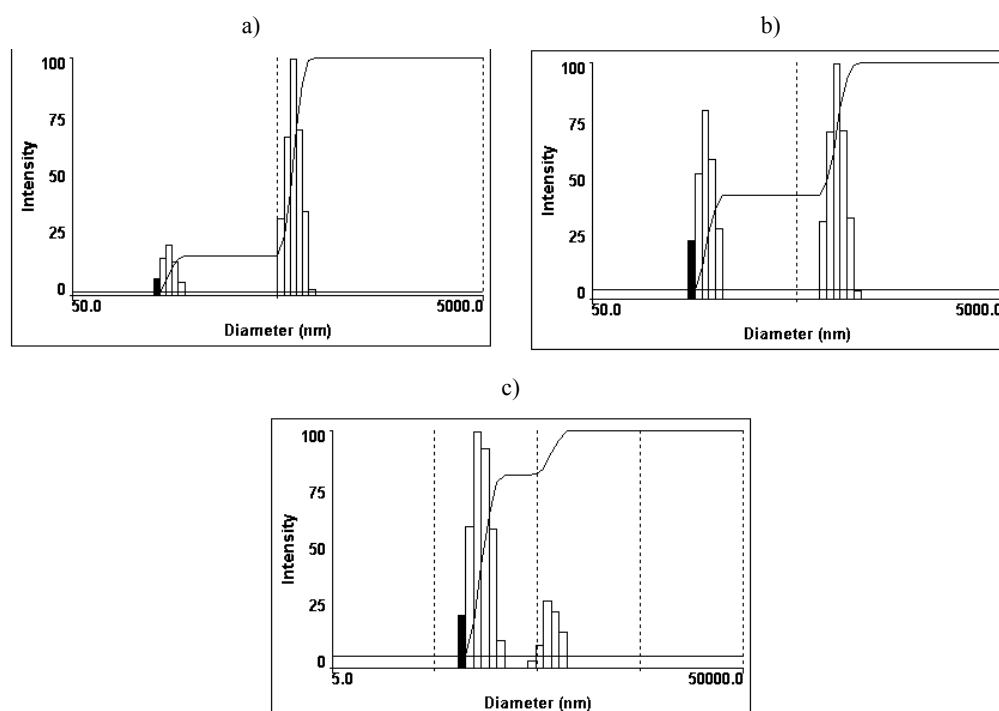


Fig. 1. Particle-size distribution: AQUAREX (a), AQUACOL (b), FORTELUX (c)

The particle-size analysis was carried out with the instrument ZetaPALS (Brookhaven Instruments Corp., USA). The results obtained are shown in figure 1. If the particle-size distribution is determined, it is possible to use ceramic microfiltration membranes with a nominal pore size of $0.1\ \mu\text{m}$ to separate the paints.

The total solid content (in wt %) in the experimental samples was determined. The values calculated are shown in table 1.

Table 1

Total solids content of used paints

Sample	wt %
AQUAREX	53.8
AQUACOL MAT	48.3
FORTELUX AQUA	36.3

2.2. MEMBRANE

Tubular asymmetric multilayered membranes (Terronic, a.s., Czech Republic) were used for the experiments. They consist of a thin layer deposited on an internal

surface of alumina support. The characteristic parameters of the membrane are as follows: length L , 0.25 m; internal diameter d_i , 6×10^{-3} m; nominal pore size d_p , 0.091 μm ; mean membrane resistance R_m , $1.17 \times 10^{12} \text{ m}^{-1}$ (obtained from water flux measurements); membrane surface area A_m , $43.35 \times 10^{-4} \text{ m}^2$. A new membrane was used in each experiment, and before running the experiment a pure water flux of deionised water was measured.

3. EXPERIMENTAL METHOD

The microfiltration apparatus used is shown schematically in figure 2. The circulating loop was made of stainless steel and consisted of a three-litre feed suspension reservoir, pump and a membrane module. The loop was equipped with a pressure- and flow-monitoring system. The cross-flow velocity was controlled by establishing the pump efficiency. The operating pressure (and hence the transmembrane pressure) in the loop was controlled by a needle valve at the module outlet; both parameters varied independently. The loop was also equipped with a temperature controller.

Basic microfiltration tests were performed with demineralized water in order to find fundamental membrane parameters. The value of pure water flux was a measure of the degree of membrane cleaning. During all tests, filtration was run at a constant cross-flow velocity of either 2 or 4 m s^{-1} and a constant pressure in the range of 50–150 kPa. In the experiments, the concentration of the suspensions used was 2% by weight.

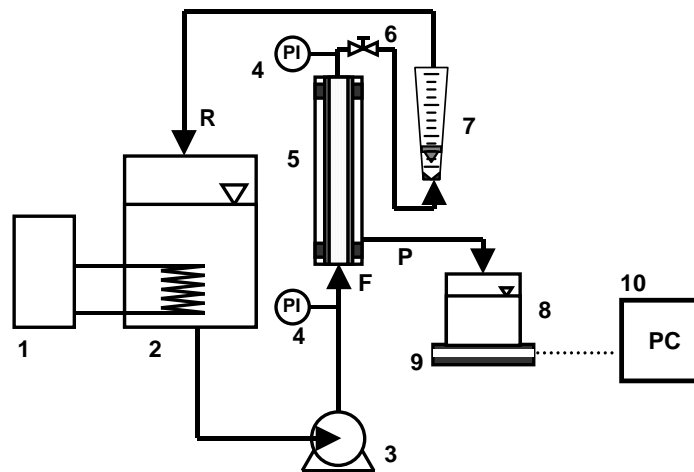


Fig. 2. Scheme of microfiltration experiments:
 1 – thermostat, 2 – dosing tank, 3 – pump, 4 – sensor of pressure, 5 – membrane module,
 6 – needle valve, 7 – rotameter, 8 – beaker for permeate, 9 – scale, 10 – output on PC,
 F – feed, P – permeate, R – retentate

Before each filtration experiment the resistance of membrane was measured. The membrane was inserted into the membrane module, and deionised water was circulated in the test loop at the pressure of 100 kPa and the velocity of 1 m s^{-1} for about 30 minutes. During this time a constant value of the water membrane permeability was measured. Based on the permeate flow rate measured, the membrane resistance R_m was calculated:

$$R_m = \frac{\Delta P}{\mu_p \cdot J_w}, \quad (1)$$

where μ_p is the dynamic viscosity of the permeate, J_w stands for the permeate flux for deionised water and ΔP is the transmembrane pressure.

After this measurement, the paint suspension was introduced to the reservoir and filtration started. The operating pressure as well as the feed velocity were adjusted by the control system. The stock dispersed phase was kept at a constant temperature of $25 \text{ }^\circ\text{C}$. The flux through a membrane was measured by weighing permeate and timing the collection period (by use of scales interfaced with a computer). Both retentate and permeate were recirculated back into the reservoir. Therefore, their concentration in the recirculation loop remained virtually constant. The experiment was stopped when a permeate flux had reached a constant value.

After each set of experiments the unit and the membrane were rinsed with deionised water. The membrane was dried and regenerated at $550 \text{ }^\circ\text{C}$. Then the pure water flux was measured again under the conditions of the initial test until the steady state was attained. From this value the membrane resistance was calculated again. The tendency of the membrane to foul irreversibly can be calculated from the difference between the two resistances (i.e. the resistance “before” and “after” filtration).

The total filtration resistance R_t was calculated from:

$$R_t = \frac{\Delta P}{\mu_p \cdot J_\infty}, \quad (2)$$

where J_∞ is the steady-state permeate flux. The difference between the total filtration resistance and the membrane resistance is filter cake resistance R_c .

4. RESULTS AND DISCUSSION

4.1. MICROFILTRATION EXPERIMENTS

All the charts are plotted for each paint separately.

Figure 3 shows the results of the cross-flow microfiltration experiments performed at various process pressure and cross-flow velocity for AQUAREX suspension.

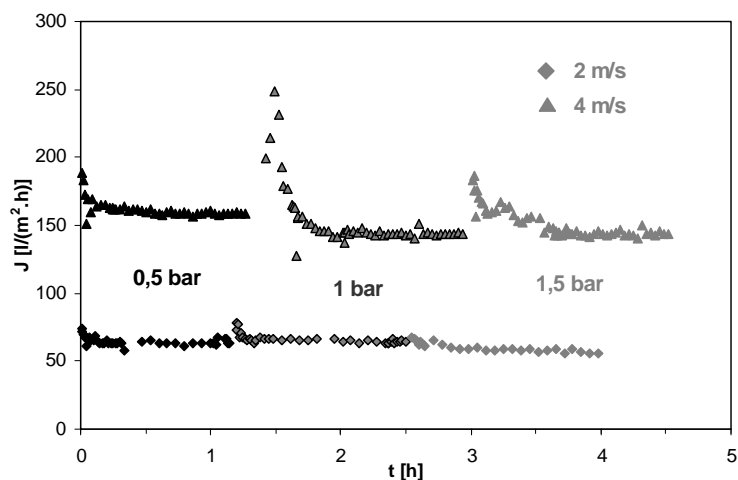


Fig. 3. Microfiltration efficiency versus pressure and cross-flow velocity for AQUAREX suspension

It is obvious from the figure that the values of permeate flux decrease during the separation processes at both cross-flow velocities. This is caused by concentration polarisation in the area close to the membrane surface or formation of filter cake on its surface.

The concentration polarisation is completed and affects the value of permeate flux when the the Brownian diffusion of particles from membrane surface and the shear stress caused by liquid flow are in equilibrium. At this moment, the permeate flux achieved a constant value.

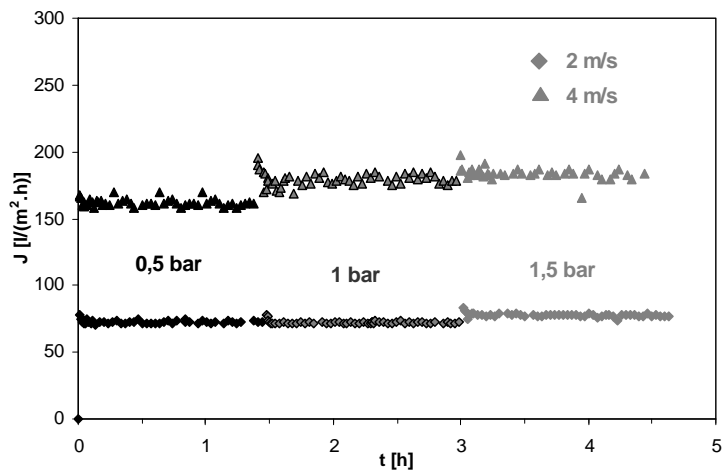


Fig. 4. Microfiltration efficiency versus cross-flow velocity and process pressure for AQUACOL suspension

Figure 4 shows the results of the cross-flow microfiltration experiments performed at various pressure and cross-flow velocity for AQUACOL suspension. As can be seen the filter cake formed on the membrane surface is not as thick as in the AQUAREX case.

The microfiltration of FORTELUX suspension is shown in figure 5. It can be seen that no filter cake was formed in this separation process. The permeate flux has the same value during experiments at both cross-flow velocities. The lower value of permeate flux was caused by smaller particle size of the FORTELUX suspension (see figure 1).

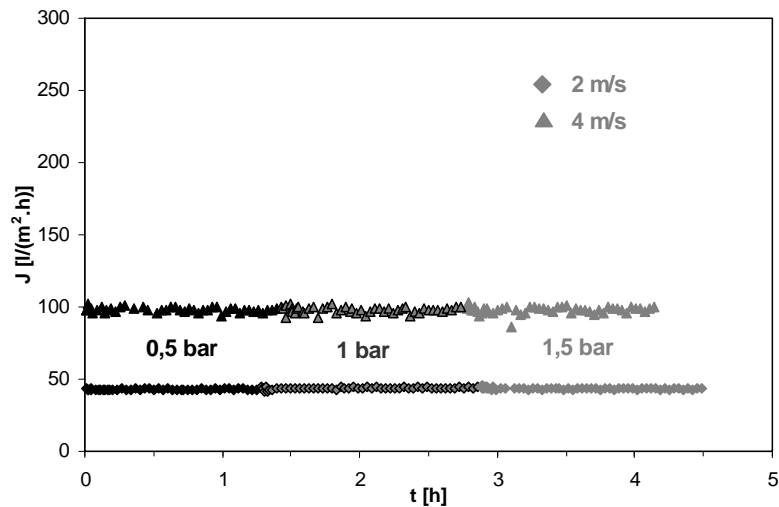


Fig. 5. Microfiltration efficiency versus cross-flow velocity and process pressure for FORTELUX suspension

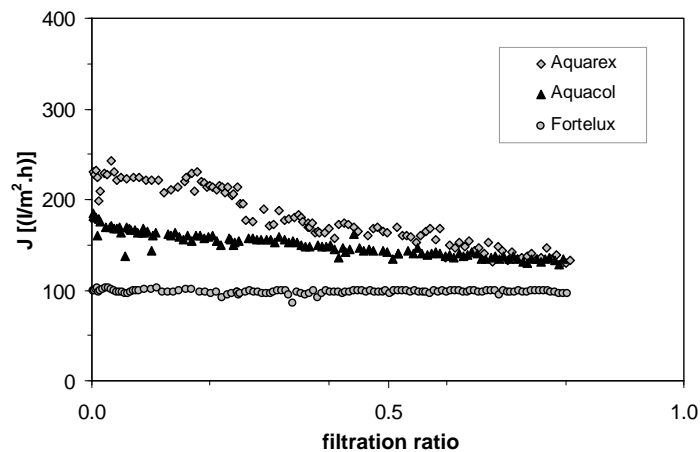


Fig. 6. The influence of filtration ratio on permeate flux

Figure 6 shows the influence of filtration ratio FR on the value of permeate flux. Filtration ratio can be expressed by

$$FR = \frac{m_P}{m_{F0}}, \quad (3)$$

where m_P is an actual weight of permeate and m_{F0} is an initial feed weight.

It can be seen that the permeate flux decreases with an increase in the concentration of particles in suspension, which is typical of microfiltration. Nevertheless, the values of the permeate flux are quite high, more than $100 \text{ dm}^3/(\text{m}^2 \cdot \text{h})$. It can be deduced from these results that the microfiltration of wastewater from the water-based paint industry will be worthwhile alternative to the other treatment methods.

The values of COD in permeates are given in table 2. It can be seen that rated values are below the limits valid for the Czech Republic.

Table 2

The COD values in permeates

Sample	COD [$\text{mg O}_2/\text{dm}^3$]
AQUAREX	815
AQUACOL MAT	2230
FORTELUX AQUA	2040

4.2. MEMBRANE REGENERATION

The membranes used were regenerated in an electric furnace at $550 \text{ }^\circ\text{C}$ for 2 hours. After very slow cooling in the furnace (for ca 24 hours) the regenerated membranes were left to soak up the demineralised water for 24 hours and then their resistance was measured again. The results of experiments are summed up in table 3. It is evident that the regeneration of ceramic membranes was successful.

Table 3

Membrane resistance “before” microfiltration and “after” regeneration

Sample	R_m [m^{-1}]	R_{mI} [m^{-1}]
AQUAREX	$7.63\text{E} + 11$	$7.72\text{E} + 11$
AQUACOL MAT	$6.20\text{E} + 11$	$6.77\text{E} + 11$
FORTELUX AQUA	$6.39\text{E} + 11$	$6.40\text{E} + 11$

5. CONCLUSION

The results of experiments show the possibility of using the cross-flow microfiltration as a means of separating each suspension tested. The values of COD in permeates were below the limits.

The treatment should be run at a lower process pressure (0.7 bar) and higher cross-flow velocity (4 m/s). The partial disturbance and washing away a membrane filter cake are caused by turbulence in feed at higher cross-flow velocity, thereby they decrease the resistance of the membrane to the permeate flow. The process pressure should also be below the value of limiting flux, where membrane pores are not blocked and a gel layer is not formed or is significantly reduced.

It is suitable to use ceramic microfiltration membranes for this kind of suspension, which can be regenerated at a high temperature.

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