The Influence of the Concentration of Dissolved Substances in the Effluent Sulfate Pulp and Paper Mills on the Productivity of Semi-Permeable Membranes

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Received: November 14, 2012 / Accepted: December 16, 2012 / Published: May 25, 2013.

Abstract: The ability of treatment of pulp and paper production wastewater is showed by carbon-graphite and polymeric membranes. The influence of lignins, organic and inorganic substances containing in wastewater on specific capacity is studied. Capacity calculation of different types of membrane is suggested.

Key words: Membrane, specific capacity, sulphate pulp mill, waste water.

1. Introduction

The pulp and paper industry (PPI), along with woodworking enterprises occupy first place in terms of waste water, wasting almost 1.5 billion m³ of wastewater per year.

Waste water from PPI entering on the treatment facilities contain considerable amounts of suspended and dissolved substances both organic and inorganic. Their composition is very diverse. This is due to the fact that during the production of cellulose about 50% of organic substances of wood goes into solution, forming a concentrated liquor, some of which (5%-20%) falls in the effluent.

The use of membrane technology in the pulp and paper industry is most promising in three ways [1]:

- Obtaining commercial products of improved quality.
- Pre-concentration of liquor by reverse osmosis in advance of concentration by evaporation [2-4].
- Membrane technology can also be used to concentrate the weak liquor, which formed at the stage of pulp washing.

The objective of this work was to study the influence of the concentration of multicomponent solutions on the specific productivity of membrane separation process, and getting the dependencies that could be recommended for technological calculations of membrane equipment for wastewater treatment. [5, 6]

2. Experiments

Studies were conducted on model solutions prepared by diluting the concentrated black liquor and real solutions of sulphate pulp and paper industry wastewater. We used as ultrafiltration (carbon graphite) membranes and reverse osmosis (composite) membranes with the characteristics shown in Table 1.

When choosing a membrane for process of wastewater treatment guided by the fact that the development of generalized method of calculation needed a membranes made of different materials and different specific productivity, selectivity and the degree of “compactibility” in a fairly wide range.
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Table 1  Characteristics of the membranes.

| Type of membrane | Conditional notation (brand name) | The pore size (μm) | The selectivity of the membrane $\varphi$ of 0.15% solution of NaCl (%) | Specific productivity of clean water $G_0$ (l/m²·h) |
|------------------|-----------------------------------|--------------------|--------------------------------------------------------------------------|-----------------------------------------------|
|                  |                                   |                    | $P = 1.96$ (MPa) | $P = 3.43$ (MPa) | $P = 1.96$ (MPa) | $P = 3.43$ (MPa) |
| Carbon-graphite   | 1U 0.4-0.6                        | -                  | -                          | -                          | 55.83               |
|                  | 2U 0.4-0.6                        | -                  | -                          | -                          | 56.23               |
|                  | 3U 0.6-0.8                        | -                  | -                          | -                          | 69.21               |
|                  | 4U 0.6-0.8                        | -                  | -                          | -                          | 68.44               |
|                  | 5U 0.8-1                          | -                  | -                          | -                          | 98.105              |
| Composite        | OFAM -                            | 79.60              | 86.72                      | 29.61                      | 32.86               |
|                  | MGA-80 -                          | 72.55              | 80.10                      | 24.14                      | 27.04               |
|                  | MGA-90 -                          | 89.04              | 91.24                      | 20.53                      | 23.40               |
|                  | OPAM -                            | 85.32              | 89.84                      | 28.24                      | 31.91               |

Fig. 1  The experimental setup of membrane separation. (1) container, (2) cock, (3) pump and (4) membrane module.

The concentration of dissolved solids were determined by standard methods. The timing of the experiments ranged from 1 to 40 h, depending on the operating pressure, type of membrane and quantity of extracted samples needed for analysis [7].

Schematic diagram of the apparatus is shown in Fig. 1.

In the experiment recorded the concentration of the filtrate, and the performance of the membranes.

Analysis of published data on the dependence of the osmotic pressure of the solution of Na$_2$SO$_4$ and sulphate liquor [1] of the solution concentration (Fig. 2) suggests that Na$_2$SO$_4$ is a major component that contributes to the osmotic pressure of sulphate liquor. Based on this conclusion, the study of the influence of the concentration of dissolved substances in the effluents of sulfate pulp and paper industry on the specific productivity, count towards only the ion content of Na$^+$. In the generalized method of determining, the productivity of different types of membranes, used productivity in the shape of a relative value of $G/G_0$, for the possibility of applying the developed methodology to the membranes that differ by type of material and productivity. Fig. 2 shows the experimental dependence of the relative productivity (the ratio of the productivity of the membrane $G$ to its productivity for distilled water, $G_0$, containing approximately 10 mg of Na$^+$/l and in some cases determined by the manufacturer and indicated in the passport of the membrane) of carbon-graphite membrane and composite membranes at an different operating pressure on the logarithm of the concentration of sulfate liquor mg of Na$^+$/l.

3. Results and Discussion

The analyzing the experimental data revealed that it is possible to determine productivity of the membranes as a function on the concentration of sulfate liquor without conducting a series of experiments. We propose the following method of constructing design line:

- With the help of Fig. 2, or other literary data for depending on the osmotic pressure of the concentration
of Na₂SO₄ at an operating pressure, is determined by the limiting concentration of sodium ions \( x_{lim} \), in which there is no driving force for membrane separation process, and, hence, productivity;

- For any type of membrane relative performance will be equal to unity at a concentration of 10 mg of Na⁺/l.

- Line, drawn through these two points of the described by the equation:

\[
\frac{G}{G_0} = b - c \cdot \log x_i
\]  

(1)

\( c \), the slope of the line; \( b \), a point of intersection with the axis of \( y \).

Lines constructed by using the proposed method in Fig. 2 (black solid line in the field of experimental data), demonstrate that this technique are useful for assessing the performance of different types of membranes depending on the concentration of wastewater kraft pulp production, in the working range of concentrations.

4. Conclusions

Thus, the presented results of experiments on the separation of sulfate wastewaters with the use of composite and carbon-graphite membranes, allow us to conclude that the specific productivity of different types of semi-permeable membranes in a wide range of concentrations of these flows can be calculated with sufficient accuracy. The calculation of the productivity of membrane systems is conducted on the basis of passport data for \( G_0 \), and background data on...
the concentrations of Na⁺-ions in a solution of Na₂SO₄, in which the osmotic pressure becomes equal to the worker and the permeability of the membrane vanishes.

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