

Heavy metal removal using reverse osmosis

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The aim of this work was to study reverse osmosis characteristics for copper, nickel and zinc removal from technological aqueous solutions. Reverse osmosis (RO) is a separation process that uses pressure to force a solution through a membrane that retains the solute on one side and allows the pure solvent to pass to the other side. A polyamide thin-film composite membrane TW30-1812-50 was used. The difference in flux decline is significant. There is a significant difference in flux decline depending on the anions of used heavy metal salts. The heavy metal concentration also has a significant influence on the membrane separation. There is also a significant difference in flux decline depending on the transmembrane pressure.

Key words: reverse osmosis, heavy metal, copper, nickel, zinc

Introduction

Removal of heavy metals dissolved at low concentrations in water and wastewaters is often a problem that can be solved in different ways.

Application of reverse osmosis can be an effective way of heavy metal removal.

Aim of this work was to study reverse osmosis characteristics for copper, nickel and zinc removal from technological aqueous solutions.

Theoretical

Reverse osmosis (RO) is a separation process that uses pressure to force a solution through a membrane that retains the solute on one side and allows the pure solvent to pass to the other side. More formally, it is the process of forcing a solvent from a region of high solute concentration through a membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure. This is the reverse of the normal osmosis process, which is the natural movement of solvent from an area of low solute concentration, through a membrane, to an area of high solute concentration when no external pressure is applied. The membrane here is semipermeable, meaning it allows the passage of solvent but not of solute.

The membranes used for reverse osmosis have a dense barrier layer in the polymer matrix where most separation occurs. In most cases the membrane is designed to allow only water to pass through this dense layer while preventing the passage of solutes (such as salt ions). This process requires that a high pressure be exerted on the high concentration side of the membrane.

Experimental

Materials and chemicals

For copper, nickel and zinc solutions following salts were used:

- copper sulphate, p.a., $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, Merck (D),
- copper nitrate, p.a., $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$, Merck (D),
- nickel nitrate, p.a., $\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, Merck (D),
- zinc sulphate, p.a., $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, Merck (D).

Equipment and methods

A laboratory reverse osmosis unit with a circulation loop of feed was used. Its scheme is shown in Fig. 1. The suspension was pumped from the feed tank to the membrane module with RO membrane. Permeate flowed to the collecting beaker placed on an electronic balance. In regular time intervals the actual

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weight of permeate was recorded. Permeate was periodically returned to the feed container to prevent change in the feed concentration.

The RO membrane was a polyamide thin-film composite membrane TW30-1812-50 schematically shown in Fig. 2.

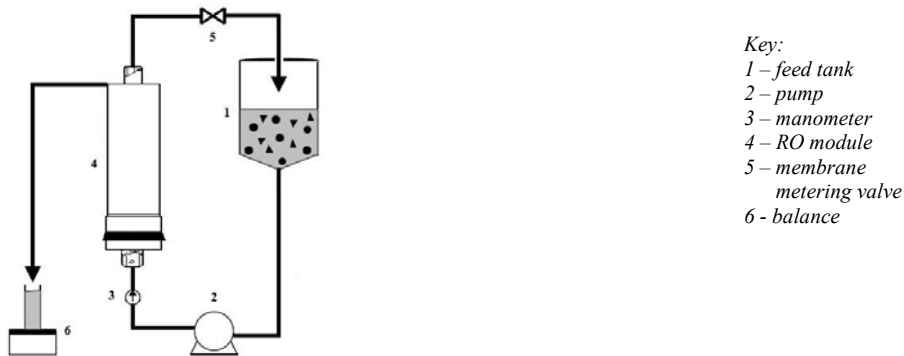


Fig. 1. Scheme of a reverse osmosis unit with a polyamide thin-film composite membrane with recirculation of retentate and permeate.

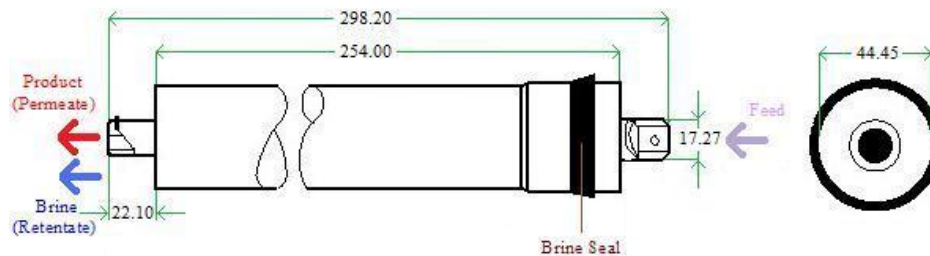


Fig. 2. Polyamide thin-film composite RO membrane TW30-1812-50.

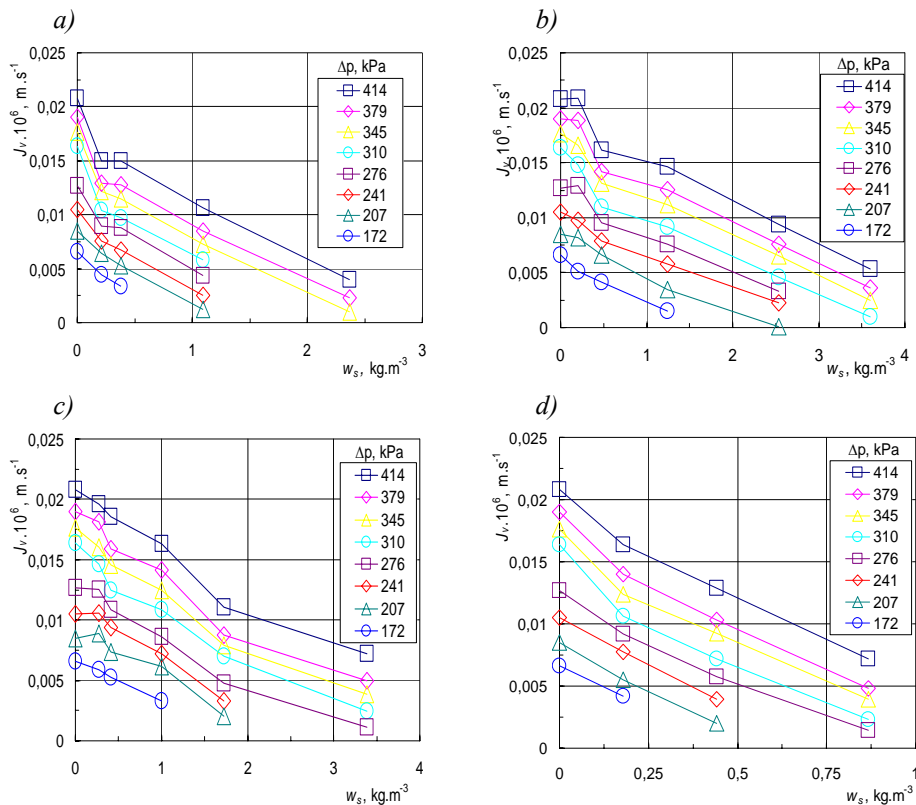


Fig. 3. Experimental data for permeate flux through the membrane vs. aqueous solution concentration a) $\text{Cu}(\text{NO}_3)_2$, b) CuSO_4 , c) ZnSO_4 and d) $\text{Ni}(\text{NO}_3)_2$.

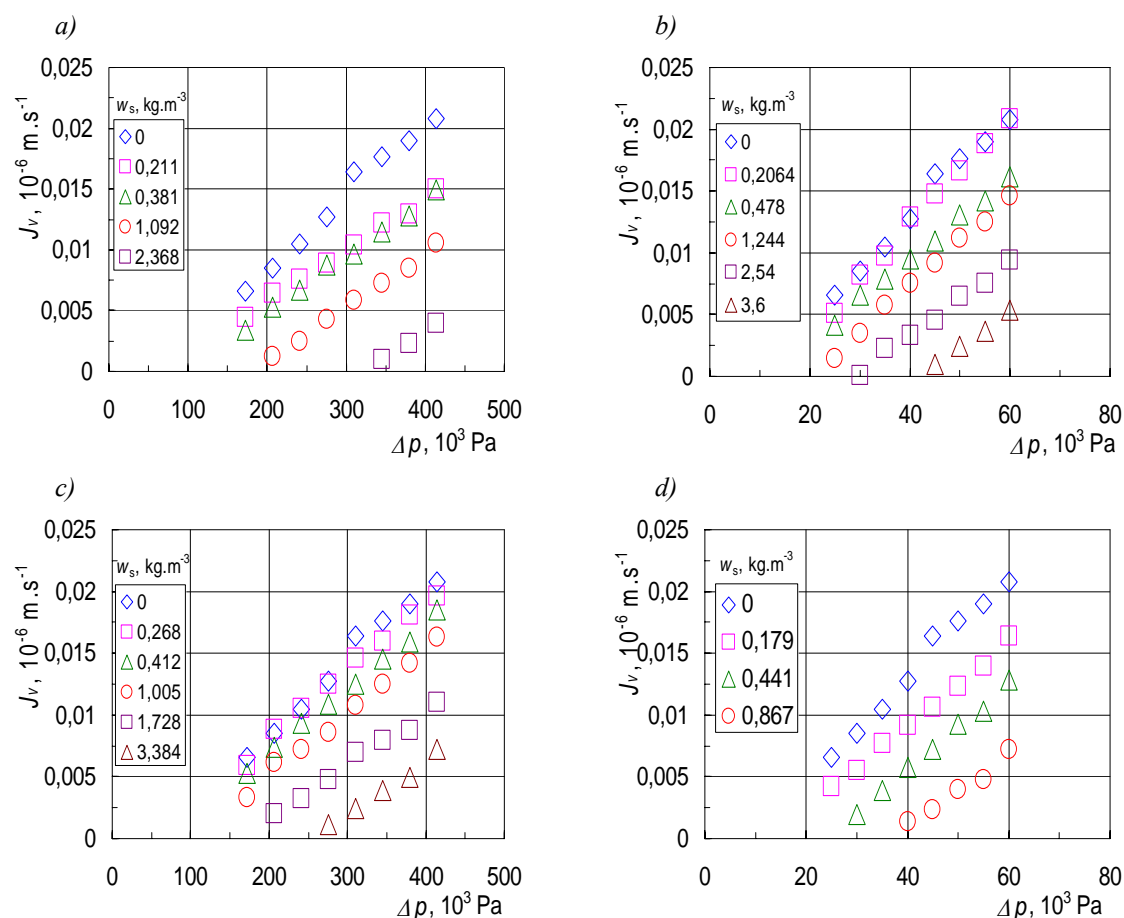


Fig. 4. Experimental data for permeate flux J_V through the membrane vs. transmembrane pressure Δp depending on solution concentration w_s , for a) $\text{Cu}(\text{NO}_3)_2$, b) CuSO_4 , c) ZnSO_4 and d) $\text{Ni}(\text{NO}_3)_2$.

Results and discussion

Basic characteristics of the RO membrane were estimated for distilled water as model solutions for the permeate. The volumetric flux of the permeate through membrane is related to transmembrane pressure difference, Δp , by relation

$$J_V = L \cdot \Delta p$$

where L is the permeability of membrane.

According to

Fig. 3 there is a difference in flux decline depending on the solution used whilst there is not a significant difference in the flux for different solution for the same transmembrane pressure. There is also a significant difference in the rate of the decline.

For copper nitrate (fig. 3a) there is a significant decline of flux up to the salt concentration 0.4 mg.l^{-1} for transmembrane pressure $413.69 - 275.79 \text{ kPa}$. For higher salt concentrations the flux decline is linear and less sharp. For transmembrane pressures less than 275.79 kPa the flux decline is linear.

For copper sulphate (fig. 3b) there is no influence of the salt for concentrations $0 - 0.2 \text{ mg.l}^{-1}$. There is a significant decline for concentrations $0.2 - 0.5 \text{ mg.l}^{-1}$. From 0.5 mg.l^{-1} the decline is linear and less sharp.

For zinc sulphate (fig. 3c) and nickel nitrate (fig. 3d) the flux decline is linear.

According to the results presented in Fig. 4 the permeate flux J_V is increasing with the increasing transmembrane pressure Δp . This relation was demonstrated for all concentrations of solutions $\text{Cu}(\text{NO}_3)_2$, CuSO_4 , ZnSO_4 and $\text{Ni}(\text{NO}_3)_2$.

Conclusion

According to the results of RO filtration of $\text{Cu}(\text{NO}_3)_2$, CuSO_4 , ZnSO_4 and $\text{Ni}(\text{NO}_3)_2$ using a polyamide thin-film composite membrane TW30-1812-50 the difference in flux decline is significant.

With increasing concentration the permeate flux is decreasing.

When comparing copper nitrate and copper sulphate there is a significant difference in flux decline, thus it is possible to observe the influence of the anions.

The experiments demonstrate that the heavy metal concentration has a significant influence on the membrane separation. With low heavy metal concentration the permeate flux was sharply decreasing whilst with higher heavy metal concentration the decline is linear. With increasing heavy metal concentration at low transmembrane pressures the flux dependence on the concentration was very low.

The experiments demonstrate that the transmembrane pressure also has a significant influence on the membrane separation.

Acknowledgement

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References

- [1] Sudilovskiy, P. S., Kagramanov, G. G., Kolesnikov, V. A.: Use of RO and NF for treatment of copper containing wastewaters in combination with flotation. *Desalination* 221, (1-3), 2008, pp. 192-201.
- [2] Sungyun Lee, Eunkyung Lee, Jinsung Ra, Byungcheon Lee, Suhan Kim, Seok Ho Choi, Sang Don Kim, Jaeweon Cho: Characterization of marine organic matters and heavy metals with respect to desalination with RO and NF membranes. *Desalination*, 221 (1-3), 2008, pp. 244-252.
- [3] Qdais, H. A., Moussa, H.: Removal of heavy metals from wastewater by membrane processes: a comparative study. *Desalination* 164 (2), 2004, pp.105-110.