APPLICATION OF NANOFILTRATION TO THE TREATMENT OF ACID MINE DRAINAGE WATERS

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ABSTRACT

This study investigated the separation of uranium and other elements in high concentrations from acid mine waters at Caldas Uranium Mining, in the southeast of Brazil, using nanofiltration membranes. Nanofiltrarion is widely used in water treatment due to the lower energy requirements and higher yields than reverse osmosis. Separation characteristics are dependent on both the molecular size and charge of the dissolved species in the feed solution as well as membrane properties. In this investigation the potential of nanofiltration to removed dissolved species like uranium from acid mine water drainage was measured. Two composite aromatic polyamide commercially membranes of FilmTec/Dow were tested and it found that uranium rejections of greater than 90% and also showed potential for the separation of aluminum and manganese.

1. INTRODUTION

Due to the dynamics and persistence, one of the most serious problems of mining industry is Acid mine drainage (AMD). If left untreated AMD can contamine groundwater and local watercourses, damaging the health of plants, wildlife and fish [1, 2]. In the southeast of Brazil, in the state of Minas Gerais (Poços de Caldas Municipality) a uranium mine generates acid water, which contains uranium, thorium and other elements like maganese, sulfate, aluminum and iron in concentrations above the permissible levels for discharging. The acid water is treated with lime to reduce the level of contaminants and to comply with the recommended levels for discharging according to Brazilian legislation [3]. In the present study, process conditions for uranium recovery from acid mine water by nanofiltration (NF) membranes was studied, in order to minimize uranium content into the acid water. NF is a crossflow, pressure driven process that is characterized by a membrane pore size corresponding to molecular weight cutoff of approximately 200-1000 dalton, and operating pressures of 150-500 psi (10-34 bar). NF is primarily used to separate low molecular weight organic and multivalent salts from monovalent salts and water [5, 6]

2. EXPERIMENTAL

2.1. Materials and Methods

2.1.1. Sample (Acid mine water)

The liquid sample was collected at the point 075 from the BNF (Bacia Nestor Figueiredo) located in the uranium mine of Caldas (Caldas Uranium Mining and Extraction Plants – CUMEP), in the southeast of Brazil. The concentrations of cations were analysed by ICP-OES model OPTIMA 2100 DV Perkin-Elmer and anions by Ion Chromatography model ICS-1000 Dionex. In Table1 are presented the composition of acid mine water and levels permitted for disposal in the environment defined by Brazilian legislation [3].

Table 1. Composition of the acid mine water

Species	Concentration (mg L^{-1})	Permissible level (mg L^{-1})
U_3O_8	13.00 ± 0.20	**
Al	254 ± 2	*
Mn	115.0 ± 1.5	1
Fe	0.77 ± 0.04	15
SO_4	1508 ± 15	*
Ca	89.90 ± 1.00	*
F$^-$	169.20 ± 2.00	10
Mg	8.84 ± 0.10	*
Ba	65.50 ± 0.80	5
P	<0.05	*
Na	1.70 ± 0.02	*
K	9.70 ± 0.10	*
Cl	0.21 ± 0.01	*
Si	13.10 ± 0.20	*

*Level not set by Brazilian legislation [3]
** 1×10^{-3} µCi/mL - Level established by CNEN [4]

2.1.2. Membranes and System Operation

The membranes used in this study were the NF and SWNF provided by Dow/Filmtec. A lab-scale cross- flow NF system with effective membrane area 119 cm^2 and reservatory of 10 L capacity was employed in this study. The operation pressure used for the experiments were 5, 10 and 15 bar. All experiments were carried out in order to check the maximum water recovery in terms of the volume filtered and the quality of the permeate. Aliquots of permeate of 20, 40, 60 and 80% of the feed volume were collected and analyzed.

2.1.3. Analytical Methods

The concentrations of uranium, aluminum and manganese in feed, retentate, and permeate were analysed by ICP-OES model OPTIMA 2100 DV Perkin-Elmer. During all analyses, multiple analyses (at least three times) were done on a single sample for analytical precision.

3.   RESULTS AND DISCUSSION

3.1. Membrane Evaluation

The degree to which material passes through the membrane is generally evaluated in terms of rejection of a solute. The rejection can be calculated through the equation 1.

$$R = 100 \text{ x } (1 - C_p / C_f) \tag{1}$$

where R is the rejection, C_p is the solute concentration in the permeate and C_f is the solute concentration on the feed.

The effect of pressure in the rejection of membranes was verified through a series of experiments using polyamide nanofiltration membranes in which the rejections were measured under three applied pressures.

The initial rejections achieved with each membrane using operational pressure of 10 bar, are listed in Table 2. These values correspond to the rejection when a permeate volume equal to 20% of the feed volume has been produced. Each experiment was continued until a permeate volume equal to 60-80% of the feed volume was produced. The date in Table 2 show the rejections for Al, Mn and U. High efficiencies were achieved by membrane for the rejection of aluminum and manganese (98-99%) in these experiments, however for uranium both membranes showed lower rejection around 91%. The high rejection of these ions is due to the separation mechanism of these membranes that involves repulsive forces between the ions and the polyamide membranes.

Table 2. Initial rejections for 20% permeate

Membrane	Rejection (%)		
	Al	Mn	U
SWNF*	99.2	98.9	91.2
SWNF*	98.2	98.0	89.5
NF	99.4	98.3	90.5

* duplicate experiments with separate membranes

The Figures 1, 2 and 3 illustrates the rejection behavior for aluminum, manganese and uranium upon pressure. Rejection was strongly dependent of operational pressure: higher rejection at higher pressure. The increase in rejection at higher pressures is generally explained by a shift in the transport mechanism across the membrane. At lower pressures a diffusive transport of salts occurs, which accounts for the lower rejections and at higher pressures convective transport of salts through the membrane becomes dominant.
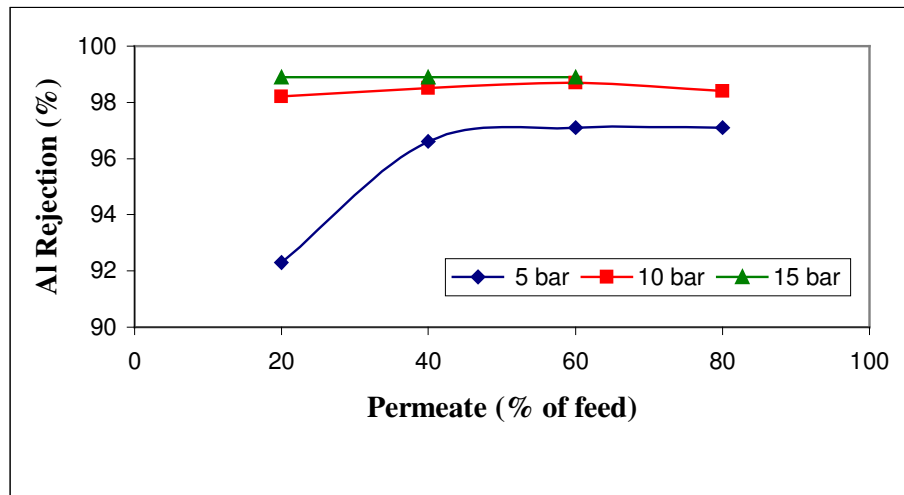
Figure 1. Aluminum rejection as a function of permeate flow at different pressures (Membrane SWNF)
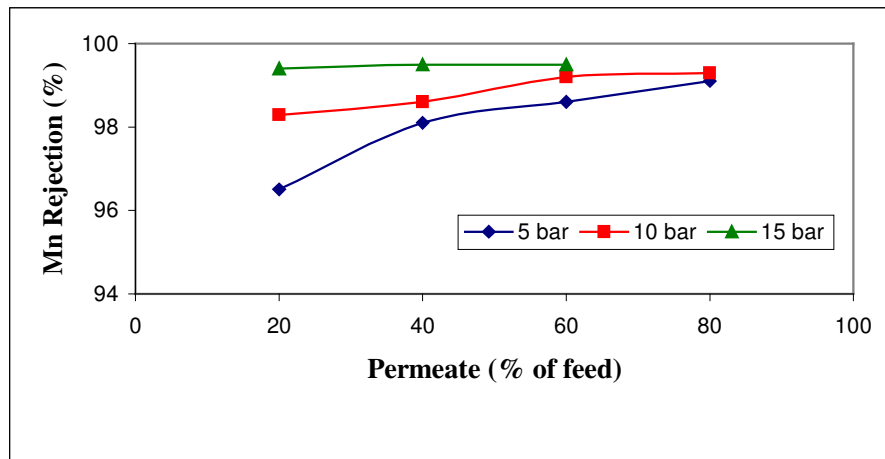

Figure 2. Manganese rejection as a function of permeate flow at different pressures (Membrane NF)
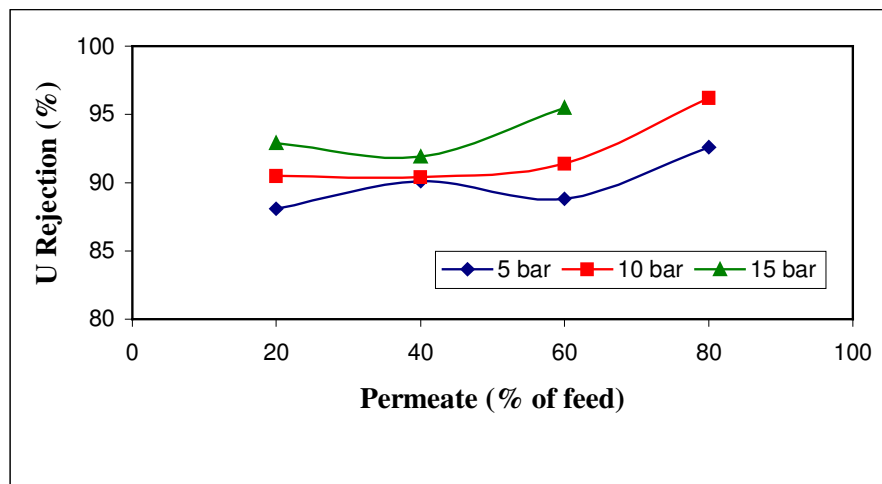

Figure 3. Uranium rejection as a function of permeate flow at different pressures (Membrane NF)

In Table 2, the data are presented for permeate flows equal to 80% of the feed volume. The purpose of this experiment was to obtain the maximum water recovery in terms of the volume and quality of the permeate. As would be expected, the rejection for each solute is similar to those presented in Table 1.

Table 2. Overall rejections for 80% permeate and 10 bar

Membrane	Rejection (%)		
	Al	Mn	U
SWNF*	99.5	98.2	91.6
SWNF*	98.4	98.1	89.5
NF	99.1	99.3	96.2

*Duplicate experiments with separate membranes

High rejections for Al and Mn were achieved with both SWNF and NF membranes having 99.5% for aluminum and 99.3% for manganese. The rejection of uranium was higher with NF membrane achieving rejection of 96%. This is due a combination of surface charge of membranes and physical size and ionic charge of the anions complex, which are hindered from passing through the membrane pores. The rejection lower of uranium can be due your concentration low in the feed solution compared with the concentration of aluminum and manganese (Table 1). This results are consistent with those found in literature.

4. CONCLUSIONS

From the point of view of environmental protection, it seems that under given operating conditions, nanofiltration can be seen as an efficient process to remove heavy metals from acid mine drainage waters, as illustrated by the experimental results reported in this paper.

5. REFERENCES

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