Mine Water Purification by Reverse Osmosis

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During the past few years, the physical separation process called Reverse Osmosis has been mentioned frequently for applications involving the purification of waste water. The work described herein describes the operation of a small reverse osmosis pilot plant using commercially available membranes to treat various mine process and waste water streams. It is important in the mineral processing industry to minimize the discharge of materials such as heavy metals, arsenic and cyanide to the environment. The present work, carried out in co-operation with several mines points out the different technical problems which need to be solved before all of the pollution problems from the mining industry can be solved.

The basic principle of reverse osmosis is depicted in Figure 1. Reverse Osmosis being, as the name implies, the reverse of the familiar "osmosis process". In this operation, very high pressures are used to reverse the natural osmotic pressure and hence produce from the feed water a high volume permeate solution which has passed through the semi-permeable membranes and a low volume concentrate solution.

From an operating point of view, reverse osmosis suffers the following limitations:

a) Treatment is expensive. Quoted values of 80¢/1000 gallons of effluent are common.
b) Streams with suspended solids pose problems.
c) Streams may contain calcium and other ions which will cause scaling problems.
d) Concentrate Disposal: Approximately 95% of inlet contamination is left in the low volume concentrate solution, hence, any potential reverse osmosis application faces the problem of concentrate disposal.

In looking at the above disadvantages, what are the potential applications involving reverse osmosis in Canadian industry? This question can be answered by the word "recycle". In certain applications, i.e. 1) Food plant wastes 2) Mine water it may be quite feasible to recycle the concentrate back into the process. This was the driving force behind the work which is described herein. One other potential use of reverse osmosis in the mining industry, is to provide contaminate free drinking water for a mine town site. This can become quite a problem in remote mineralized areas where the level of "natural" contamination can be sometimes several times higher than the drinking water standard.

Pilot plant

The small processing unit was constructed using full size Calgon or Dupont membranes to avoid scale-up problems. A diagram of the process is given in Figure 2. The heart of the system lies with the pump and regulatory valves. The pump used on this unit, a

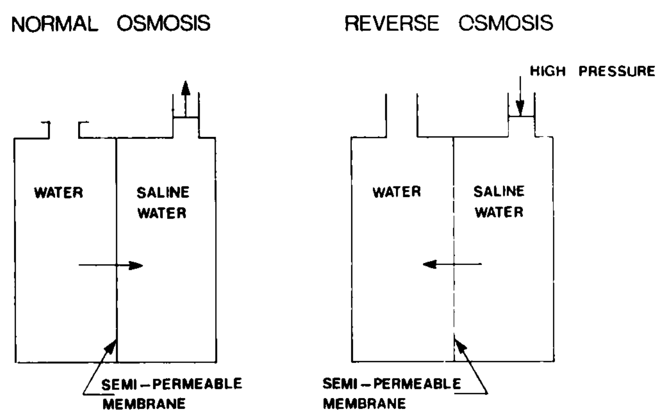

Figure 1 – Principle of reverse osmosis.

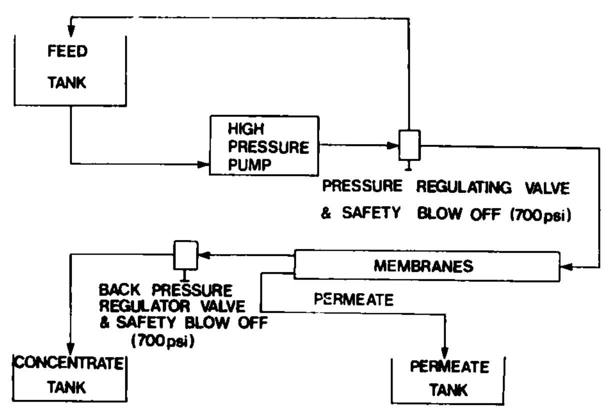

Figure 2 – Reverse osmosis pilot plant.

TABLE 1

ARSENIC REMOVAL BY REVERSE OSMOSIS

Operating pressure	400 psi.
Operating temperature	24°C.
Feed stream pH	3.1
Concentrate flow rate	6.3 cc/sec.
Permeate flow rate	17 cc/sec.
Feed concentration (p.p.m. As)	16
Permeate concentration	0.8
Concentrate concentration	57
Recovery	73%

TABLE 2

RESULTS OF BARREN SOLUTION — REVERSE OSMOSIS TRIAL

(all concentrations ppm)

Operating Pressure (psi)		200			300			400	
Solution	Feed	Permeate	Concentrate	Feed	Permeate	Concentrate	Feed	Permeate	Concentrate
Flow cc/sec.	62.5	26.5	36.0	109.8	35.2	74.6	114.4	42	72
pH	11.9	11.81	11.97	11.8	11.75	11.8	11.8	11.88	11.90
Cu	87	5.6	144	70	22.9	110.5	70.2	46.8	83.3
Pb	0.1	<0.05	0.15	0.14	<.05	0.22	0.14	—	—
Zn	26.2	2.4	38.8	25	6.4	34.4	25.1	13.5	29.9
Ni	44.9	7.89	67.6	35.8	14.0	50.4	35.8	27.1	47.2
CaO	700	95	1060	765	148	870	765	333	962
Fe	2.3	0.02	3.3	1.43	0.4	2.8	1.43	0.72	1.44
CN^- (Free)	158	40	236	130	56	192	130	97	148
CN^- (Total)	321	59	502	237	98	316	237	172	288
% Recovery		42.4			32.1			36.7	

piston unit operating at up to 650 psi, has proved to be extremely reliable. The Calgon cellulose acetate membranes were model 510 units with an operating pH range of 3-7. For alkaline conditions, the Dupont B-9-S hollow fibre membrane was used with a pH range of 4 to 11.

The equipment was first operated with a standard $CuSO_4$ solution to evaluate the effectiveness of the unit. Feeding a 100 ppm $CuSO_4$ solution into 2-510 Calgon membranes in series at 530 psi, the recovery of water was 80%. The analysis for copper was colourimetric although a visual qualitative analysis was indicated by the blue colour of the $CuSO_4$ solution.

Applications

a) *Dissolved arsenic removal by reverse osmosis*

Rosehart, et al[1] have studied the problem of soluble arsenic emissions from a typical gold processing plant. It was concluded that over 98% of the soluble arsenic was contained in the low volume quench water stream after roasting of the ore. This stream, with very low suspended solids, and a pH of 3.1 seemed a natural for the cellulose acetate membranes. The results of processing the acid quench water by reverse osmosis are given in Table 1 for an operating pressure of 400 psi. A satisfactory reduction of arsenic in the permeate is obtained but the recovery is only 73% of the total flow.

b) *Barren solution treatment*

One of the problem streams in the traditional gold mill circuit is the barren solution. In order to dissolve gold, *NaCN* is usually added to the circuit. Then zinc is added to precipitate *ZnAuCN*. The decant from this process is termed the barren solution but in reality, this solution is very rich in metallic ions as well as containing a considerable amount of Ca^{++} and CN^- which are added intentionally to the process. Typical analysis of several barren solutions used as feed in the reverse osmosis studies are given in Table 2.

Is it possible to:

i) Remove the ions from the barren solution and thus prevent an environmental problem,
ii) Recover the above ions for recycle or recovery?

The present work using reverse osmosis is an attempt to accomplish the above aims[2]. The high solution *pH* was beyond the range of cellulose acetate membranes and for this application Dupont B-9-S membranes were used. The results of three six hour runs are documented in Table 2 for operating presures of 200, 300 and 400 psi. The permeate concentrations are low and hence from a waste water purification standpoint, the results are excellent, however, the recovery is low and as a result the degree of concentration desired has yet to be achieved. In this work, no problem has been encountered with calcium scale (probably due to high pH). The differing degrees of separation for the various constituents should be noted.

Some preliminary work was done on a two stage system and the degree of concentration in each stage of the system studied seemed to be a constant.

Summary

i) A small reverse osmosis pilot plant is described.
ii) Test procedures using $CuSO_4$ are described.
iii) The use of reverse osmosis to remove dissolved arsenic from low pH mine water is examined. The results are quite encouraging and reverse osmosis might be ideal for demineralizing drinking water.
iv) Results of reverse osmosis studies on high pH barren solutions using Dupont hollow fibre membranes are discussed. The permeate concentrations are low but the degree of recovery is unsatisfactory.

References

(1) Rosehart, R. G., Lee, J. and Pattyson, G., "Arsenic and its Removal from Gold Extraction Plant Effluents", preprint 72-T-10, MMIJ-AIME, Joint Meeting, Tokyo, May (1972).
(2) Bailey, R. P., "Cases for Reclamation of Mineral Processing Water", Can. Mining Journal, June (1970).

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