CHAPTER VII

DISCUSSION AND CONCLUSIONS

7.1 Pure water permeability

The pure water permeability was a linear function of pressure (Fig. 6.1). The operating puresure was varied from 40-65 bar. The temperature was kept constant at about 30-33^{o}C.

Figure 6.1 shows the variation of flux with pressure for membrane type T2/15W. The slopes of this graph correspond to values of Rm (the membrane resistance, defined in Equation 2.1 in section 2.1.3) of 2.81 x 10^7 kPa.m^2. sec/m^3.

The pure water permeability of a module can also be used as a measure of its age, via compaction, or of clogging. In some experiments where solution was concentrated for up to 12 hours, the final pure water permeability of the membrane was only 60% of that measured at the beginning of the experiment, indicating that considerable fouling of the membrane had occured. The pure water permeate was restored to within 95% of initial value after cleaning.

Data of Table 6.1 also shows that rejection of inorganic salts (in terms of conductivity) is better than 99.9% at feed concentration of 240 μmho, clearly a very practical mean for production of pure water from tap water.

7.2 Pressure variation of flux

The effect of pressure on the trans-membrane solvent flux is shown in Fig. 6.1. From the phenomenological expression for flux (Equation 2.1 in Section 2.1.3), the solvent flux increases linearly with increasing pressure. The X - intercept is then the effective osmostic pressure of the boundary layer ($\Delta\pi$). Lines are drawn on Figure 6.1 for eight concentration of sucrose solution. The effective osmotic pressure for each concentration are given in Table 7.1.

The slopes of each line in Fig. 6.1 decrease with increasing concentration, indicating are increase in the dynamic and fouling component (Rf + Rd) to the over-all transport resistance. Values of Rf + Rd estimated from the data in Figure 6.1 are shown in Table 7.1 for each of the concentration investigated. The values of the various resistances to mass transfer are given for comparision only. The errors involved in their calculation may be large since the ΔP term is accurate only $\pm$ 1 bar and $\Delta\pi$ is accurately only to $\pm$ 1.5 bar. The error on their difference could thus be as high as $\pm$ 2.5 bar which would have considerable effect on the values of various resistants.

Table 7.1 also includes the value of osmotic pressure of sugar solution for comparison with the effective osmotic pressure at the membrane surface which demonstrate clearly the concentration polarization phenomena

Table 6.2 also indicates that within the limit of accuracy of hand-held refractometer no sugar permeates through the membrane. The rejection of sucrose is thus 100 per cent for feed concentration up to 31 Brix at operating puressure between 40-60 bar.

Table 7.1

Osmotic Pressure and Resistant Values

Conc.(%sugar)	Pure water	6.4	8.5	9.8	13.8	18.0	21.0	26.0	31.0
Osmotic pressure of solution (KPa) x 10^{-2}	0	4.7	6.3	7.2	10.4	13.4	15.8	19.5	23.2
Effective osmotic pressure at membrane surface (KPa) x 10^{-2}	0	7	8.5	11	14	18	23	30	39.5
Ro(KPa.m^2.sec/m^3)x10^{-7}	2.81	2.88	2.89	3.12	3.44	4.18	4.64	5.09	6.51
Rm(KPa.m^2.sec/m^3)x10^{-7}	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81
Rd+Rf(KPa.m^2.sec/m^3)x10^{-7}	0	0.07	0.08	0.31	0.68	1.37	1.83	2.28	3.69

7.3 Variation of flux with increasing concentration

The results shown in Figure 6.1, 6.4, 6.5, 6.8, 6.11 and 6.14 demonstrated that the transmembrane solvent flux decreases with increasing concentration, all other variables being held constant. This decreasing is caused by an increase in the effective osmotic pressure term ($\Delta\pi$) so that in the limit where the effective osmotic pressure is equal to the equal to the hydrostatic operating pressure of the system, the transmembrane flux should fall to zero. The complete drop-off was clearly observable many times when retentate concentration was high and thus indicated practical practical limit of achievable concentration.

It was observed that passing the feed solution through ultrafiltration system prior to concentrating by reverse osmosis system does improve the permeate flux of reverse osmosis system. This observation implied that large molecules and particles exert appreciable dynamic resistance. However, the two molecular weight cut-off of Ultrafiltration membranes (6,000 & 70,000) used in the study improve the flux by the same extent. The conclusion of which can not be drawn due to insufficient data. In the case of squeezed solid waste feed, ultrafiltration does not improve reverse osmosis flux.

However, passing the feed solution through ultrafiltration system prior to concentrating by reverse osmosis can help in prolonging reverse osmosis membranelife and sanitation of product. Since ultrafiltration can retend the bacteria and other large particles, so that fermentation will not occur in storage tank of the reverse osmosis system during concentrating.

Other workers have reported that particles such as fibres in the feed may help decrease dynamic resistance by aiding momentum transport through the membrane thus increase the shear-rate; such phenomena was not observed in this study. As can be seen from comparing Figure 6.4 and Figure 6.11, the flux of squeezed solid waste with much higher solid fibres is in the same order of flux from liquid waste.

7.4 Variation of flux with increasing feed pH

The effects of feed pH on permeate flux was examined by recycling concentrate and permeate back to the feed tank. So that during each experiment the feed composition remained constant, only the pH value was adjusted to the desire value by addition of NaOH. Figure 6.15 shows the results of this experiment using constnat feed concentration of 5 Brix. The transmembrane solvent flux decreases with increasing feed pH.

The figure indicated that two factors are involved; firstly the pH effects the structure and/or extents of coagulation of the solute thus changes the effective osmotic pressure at the membrane surfaces, secondly, the pH slightly change the tightness of the membranes causing changes on effective membrane resistance.

7.5 Rejection characteristics

For the reverse osmosis membrane all soluble solids were rejected base on refractive index determined, except at very high (25° Brix) retentate concentration so which some loses of sugar through the membrane was observed. The analysis of the permeate is shown in Table A.1 of the Appendix it can be seen that the quality is sufficient to be reused as boiler feed water.

7.6 Ultrafiltration system

Figure 6.9 shows that ultrafiltration permeate flux of T6/B membrane increase linearly with operating pressure. Table 6.6 indicates that rejection of soluble solid decrease with increasing pressure indicating, clearly, the convective nature of solute flux through the membrane. Therefore, the purpose of this work, operating conditions of ultrafiltration system should always kept at the maximum operating pressure subjected to economic study which is beyond the scope of the study.

7.7 Energy consideration

From calculation in Appendix C, it was also determined that if this concentration of waste material were concentrated by open evaporator the energy requirement is about 150 times as great as reverse osmosis.

Conclusions

The conclusions drawn from the research are as follow :

(1) The Reverse Osmosis pure water permeability increases linearly with increasing pressure. The reverse osmosis membrane type T2/15W has a resistance of 2.8×10^{-7} $KPa.m^2.sec/m^3$.

(2) The Reverse Osmosis and Ultrafiltration permeate flux was a linear function of pressure.

(3) The Reverse Osmosis transmembrane permeate flux decreases with increasing feed concentration.

(4) The Reverse Osmosis transmembrane permeate flux decreases with increasing feed pH.

(5) Filtration of feed solution by ultrafiltration before concentrating by reverse osmosis is necessary in order to protect Reverse Osmosis membrane and obtain sanitized product.

(6) The Reverse Osmosis membranes use was found to reject practically all solute , thus give high enough quality permeates to be reused as boiler feed water.

(7) The sugar rejection of ultrafiltration system decreases as flux through the membrane increases.

(8) The Reverse Osmosis system can concentrate liquid waste up to 25% concentration with appreciable flux, this concentrate solution can be used as substrate to fermentation processes for high quality products.

Suggestions

In Further study of this work the following suggestion are :

(1) Cost and economic analysis of membrane treatment system.

(2) Long term performance study in order to determine membrane life and the system.