proceedings of the UNESCO Regional Seminar on

TECHNOLOGY FOR COMMUNITY DEVELOPMENT IN AUSTRALIA, SOUTH-EAST ASIA AND THE PACIFIC

Alice Springs, Australia
9-11 July, 1990

Editors:

D S Mansell, D F Stewart & B W Walker

for the Organising Committee:

R J Fuller
D S Mansell
A G Marjoram
C Scollay
D F Stewart
B W Walker

PUBLISHERS

Development Technologies Unit
The University of Melbourne

AND

Centre for Appropriate Technology
Alice Springs College of TAFE
The Remote Area Developments Group of Murdoch University has been investigating the technology of Reverse Osmosis powered by photovoltaic panels. A small RO unit featuring energy recovery has been tested while connected to a solar panel. Compatibility of power supply and power demand has been achieved with the use of an inexpensive pump optimiser, eliminating the need for batteries or electronic controllers. Daily pumping durations have been extended dramatically by the use of a robust, maintenance free solar tracker. The Group is developing a larger unit with the aim of producing up to 1000 L/day of fresh water from two solar panels.

INTRODUCTION

Many inland community water sources have salinities in the range of 3000-6000 ppm, making it unsuitable for drinking water supply. Nitrate and fluoride are also often found in concentrations higher than the recommended standard (National Health and Medical Research Council, 1987). In places where surface water sources are not available or are limited, rainfall is low and groundwater salinity is high, the only possible supply of drinking water is from desalination.

Solar distillation was, until recently, the world's leading desalination technology. Its appropriateness for remote community water supply however is questionable (Walker, 1982). Reverse osmosis desalination has now superseded distillation and has been applied in the provision of drinking water worldwide (Silver, 1984).

Reverse osmosis is a pressure driven membrane separation technique which has traditionally required pressures of 40 atmospheres or more. Recently, low pressure membranes have been developed which operate at 10 atmospheres or less and, though not suited to seawater desalination, are ideal for the treatment of brackish water allowing a high production rate and a lower energy demand. The process has, however, remained a highly technical one requiring skilled supervision and ongoing maintenance. Its appropriateness for application in remote communities is therefore doubtful. Further, its energy demand, even with low pressure membranes, has made its adaptation to solar power an extremely expensive option.

The Remote Area Developments Group (RADG) of Murdoch University has been investigating the process with a view to adapting it for remote applications. The criteria for successful adaptation are seen as, 1. Simplicity, 2. Low cost, 3. Low maintenance and 4. Robustness.

DEVELOPMENT STRATEGY

The Reverse Osmosis Hardware

The amount of water treated per membrane is restricted to 10 - 15% as higher recovery ratios lead to rapid membrane deterioration. Large plants use several banks of membranes connected in series to achieve recovery ratios of 80 - 90%, leaving a highly concentrated brine which may be very difficult to dispose of. Additionally, the last few membranes in series are treating quite concentrated salt solutions. Without chemical pretreatment (complexing agents and pH control) many sparingly soluble salts commonly found in groundwater (eg. CaSO4) can exceed their solubility and precipitate out of solution as a scale which fouls the membrane (Heitmann, 1990). Post treatment dosing is also required to adjust the pH back to drinking water standard.
Very small units, typically run from generators, may use only one or two membranes and so achieve recovery ratios of only 10-20%. They require a much lower degree of pre and post treatment and brine disposal is much less of a problem (Keefer et al., 1985). The brine is only slightly more concentrated than the feed but there is a lot of it, as 80-90% of the feed is rejected. Accordingly, for every litre of fresh water produced, up to 10 litres of feed water has to be pumped up to the system pressure. In terms of the hydraulic energy requirements the process is quite wasteful and makes adaptation to solar power a very expensive option. Also, since the system pressure and recovery ratio are determined by a throttle valve on the reject line, regular supervision and adjustment would be required to cope with the varying supply of power from the solar array.

Great savings in energy can be gained by using this still pressurised waste stream to assist in the pumping of the feedwater. An example of an energy recovery system in production is shown in Figure 1. The switching valve has opened the pressurised waste stream to the back of the piston for the pumping stroke. With a flow of 90% of the total pumped flow and in excess of 90% of the pumped pressure working on the back of the piston, the motor provides only a fraction of the total energy needed to pump the system to pressure. Further, as the recovery ratio is fixed internally, no adjustment is required as power from the solar array fluctuates during the day. The accumulator evens out the flow across the membrane which would otherwise deform under the pulsed flow of a single cylinder pump.

![Diagram of energy recovery system](image)

**Figure 1.** The spool valve opens the pressurised waste flow to the back of the pump piston.

In Figure 2, the switching valve allows the waste stream, now at atmospheric pressure, to be expelled while feed water is being drawn into the pump.

The two main handicaps with this system are the fixed recovery ratio and the pulsing of water through the membrane. The fixed recovery ratio means that devices can't be optimised to suit bore water quality. It should be possible to use higher recovery ratios on reasonable quality water and
thus obtain higher volumes without aggravating membrane fouling. The single acting simplex pump inevitably causes pulsing through the membrane. The membrane is spiral wound and pulsing causes adjacent membrane layers to rub against the web-like intervening layer. This rapidly decreases membrane life. The pulsing is partially controlled by the accumulator but this becomes less effective for larger pumps. In fact it is usual to use a triplex pump for larger flow rates to avoid this pulsation. This naturally becomes an expensive and complicated option.

The RADG group has been developing a simple pumping system using double acting pumps to deliver an even flow, and energy recovery to reduce the power requirement. By scaling up the smaller field units instead of scaling down a larger plant, we hope to retain the simplicity of the former and avoid the costly and operator intensive control systems of the latter.

In the majority of cases, the salt removal efficiency does not need to be very high. Salinities of 3000 - 6000 ppm need only be reduced to 1500 ppm to meet the required standard for drinking water (National Health and Medical Research Council, 1987). Ongoing testing of the new range of low pressure membranes will continue to determine the best combination of flux rate, removal efficiency and cost.

**Solar Tracking**

A Perth company, Solar Track Pty Ltd, has invented a robust and reliable solar tracker which has only two moving parts - the two bearings. The solar tracker operates purely on the weight difference between the two half-shaded copper cylinders, each partly filled with liquid Freon. When one cylinder heats up more than the other, more Freon evaporates which forces the liquid Freon below it into the other cylinder. The weight difference rotates the tracker, keeping up with the sun all the time. A patented device in the upper shade gives the tracker a kick back last thing.
in the evening. As the panels cool, gravity takes over and the tracker rotates back to face the east, patiently awaiting the dawn.

**Pump Optimisation**

Solar panels don't produce power like a battery does. A battery provides the power at its designed voltage, say 12 V, and provides the current that the motor requires, say 4 A. The output from a solar panel is dependant on the strength of the sunshine (insolation) and power is provided in a range of Voltage/Current combinations that comprise its I/V curve. With a slowly revolving single cylinder pump, the current draw varies dramatically over the crank cycle, so the output from the panel will be shooting backward and forward along the I/V curve, only rarely encountering its zone of maximum power. Further, if the insolation level drops it may not be possible to find a point on that curve and the motor will stop.

A Perth company, Solar Focus, produces a Pump Optimiser which keeps the voltage output up so that the output from the panel is always near its maximum (Figure 3). It then delivers the required current to the motor, making up any power deficit by varying the voltage. The principle differs from full size Maximisers (Maximum Power Point Trackers) which actually track backwards and forwards along the IV curve to maintain the point of maximum power. They may be more efficient than an Optimiser but they are five times the cost.

![Graph](image)

**Figure 3.** Input voltage is selected to keep the power production of the array near its point of maximum power. Output voltage is delivered according to the current demand of the motor.

**Miscellaneous Controls**

Unlike most larger scale reverse osmosis plants, it is anticipated that no other control mechanisms will be required. It should be stressed that every control mechanism requires some power, is a source of failure and adds to both the capital and maintenance costs. In keeping with this philosophy, the pump is connected through the optimiser directly to the solar array and not through a battery bank. Batteries are only 70% efficient, so 30% of the power from a solar array is lost if batteries are used (Van Overstraeten and Mertens, 1986). Further, since only a fixed amount of solar energy is available per day, it is considered more efficient to store that energy as water than to store it as chemical/electrical energy.
EXPERIMENTAL WORK

While the development work on the prototype was in progress, a small commercially available desalinator was tested for its adaptability to solar power. The 'Powersurvivor' is a 12V unit designed for the boating market with a 5 L/h capacity and a high pressure membrane suitable for desalinating seawater. The unit was installed in a test facility on Murdoch campus and connected to a 55W solar panel via a solar pump optimiser. The panel was mounted on a solar tracker and both the tracker and the optimiser could be disarmed to evaluate their performance.

RESULTS

The typical summer production pattern of the 'Powersurvivor' coupled to the solar panel is shown in Figure 4.

![Figure 4. The hatched area represents the increased production of fresh water resulting from the use of solar tracking and pump optimisation.](image)

The tests demonstrated the benefits of the solar tracker and the optimiser on production rates. The tracker in particular produced a significant increase in production while allowing a rapid startup in the morning. The optimiser showed its benefits in keeping the unit working well through marginal conditions such as early morning, late evening and, as earlier tests showed, through periods of light cloud. The power provided by the panel in the mornings is also delivered in a high current, low voltage form by the optimiser and so gives the pump the required starting torque. The tracker and optimiser together nearly doubled the production of fresh water. From these results, it is likely that the maximum daily duration of production (in January in Perth or October in the north of the State) will be 11 to 12 hours. The maximum production rate from the Powersurvivor is approximately 65 litres from a day which recorded 12.7 hours of bright sunshine. Using the system adopted by Legge (1987) we can assume a production rate of 55 litres from an average Perth summers day of 10.7 hour of bright sunshine. Similar production rates could be expected for Alice Springs in January.

COMPUTER MODELLING OF PROPOSED UNIT

A computer model which takes into account energy recovery has been constructed and by using the flux rates of a commercially available low pressure membrane, a production rate of 83.7 L/h is expected in summer bright sunshine conditions. The experiments conducted on the Powersurvivor demonstrated the extremely long duration of pumping that can be achieved using a solar tracker
and solar optimiser. Twelve hours of pumping in Perth would therefore produce 1000 L/day from just two solar panels.

A comparison of the production rates of previous solar RO desalinators is shown in Table 1 and demonstrates the advances that have occurred in recent years.

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>YEAR</th>
<th>POWER (W)</th>
<th>PRODUCT (m³/d)</th>
<th>ENERGY CONSUMPTION (kWh/m³)</th>
<th>RATE (L/d/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peterson</td>
<td>1979</td>
<td>2750</td>
<td>1.5</td>
<td>14.7</td>
<td>0.55</td>
</tr>
<tr>
<td>SERIWA</td>
<td>1983</td>
<td>1200</td>
<td>0.7</td>
<td>13.7</td>
<td>0.58</td>
</tr>
<tr>
<td>Powersurvivor*</td>
<td>1989</td>
<td>55</td>
<td>0.065</td>
<td>10</td>
<td>1.2</td>
</tr>
<tr>
<td>Prototype**</td>
<td>1990</td>
<td>110</td>
<td>0.288</td>
<td>4.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Projected**</td>
<td>1991</td>
<td>110</td>
<td>1.0</td>
<td>1.3</td>
<td>9.1</td>
</tr>
</tbody>
</table>

* = features energy recovery  
** = features energy recovery and low pressure membranes

Table 1. Power consumption based on the nominal size of the solar array used. The Peterson and SERIWA units used fixed arrays and energy consumption is based on an assumed eight hour production cycle, whereas the next three use solar trackers which extend the pumping cycle to twelve hours. Figures are based on the maximum summer production.

CONCLUSIONS

Solar powered reverse osmosis has the potential to make a significant contribution to the health and well-being of remote communities whose water sources are not to the required drinking standard. Solar panels are maintenance free, have a life expectancy in excess of 15 years, are clean, quiet and environmentally sound. Their only failing has been their comparatively high capital cost. The use of energy recovery on the reverse osmosis plant can reduce the number of panels required to one quarter of that normally required. To this end, RADG's goal is to develop the technology to produce up to 1000 L/day of fresh water from brackish water sources, from the power of only two solar panels, with the aid of, 1. energy recovery of the waste stream, 2. low pressure membranes, 3. solar trackers, 4. pump optimisers and 5. Australia's abundant sunshine.

REFERENCES


