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SOLAR POWERED REVERSE OSMOSIS DESALINATION

D.G. Harrison and G.E. Ho

INTRODUCTION

If a bore intended for domestic supplies yields only brackish water, the intending users must either sink another bore, move to another location, drink the water as is, or employ some form of desalination technology. All options are either expensive, socially disruptive or pose serious health risks. With recent advances in reverse osmosis technology, the last option has become a realistic and viable one. To apply this normally high-tech option to remote locations however, a change in priorities becomes essential. For any technology to be successful in these regions it must satisfy the criteria for 'appropriate technology,

1) Design robustness,
2) Reliability - even at the sacrifice of cost and efficiency,
3) Low maintenance - features such as modular design, use of stock parts, screwdriver and spanner servicing and servicing which can be learnt and carried out by the community members,
4) Small scale and low cost,
5) Easy to start up and stop, and forgiving of mistakes,
6) Mobility
7) Does not need to be 'low technology', the other criteria being met.

One reverse osmosis desalinator has been assessed according to these criteria and recommendations for the most appropriate use of the technique in Aboriginal outstations have been made.

A wind powered reverse osmosis desalinator has been developed to pilot plant stage, details of which are given by Rod Robinson in this publication. For areas endowed with reliable wind regimes, such as those near the coast, Robinson's system has tremendous potential. Wind power is a more concentrated and easily harnessed than solar energy at the moment but suffers from great fluctuation over small periods, making overall systems bigger and needing more controls. There is also the problem of wind droughts which occur in the north of the State, and could leave communities in short supply. Solar powered systems can be much more compact and simple, due to the more even supply of power, and more reliable, at least away from the coast.

PERFORMANCE CRITERIA

The National Health and Medical Research Council (NHMRC 1987) and the World Health Organisation (WHO 1984) water quality criteria have been reviewed and the most critical as far as health is concerned are,

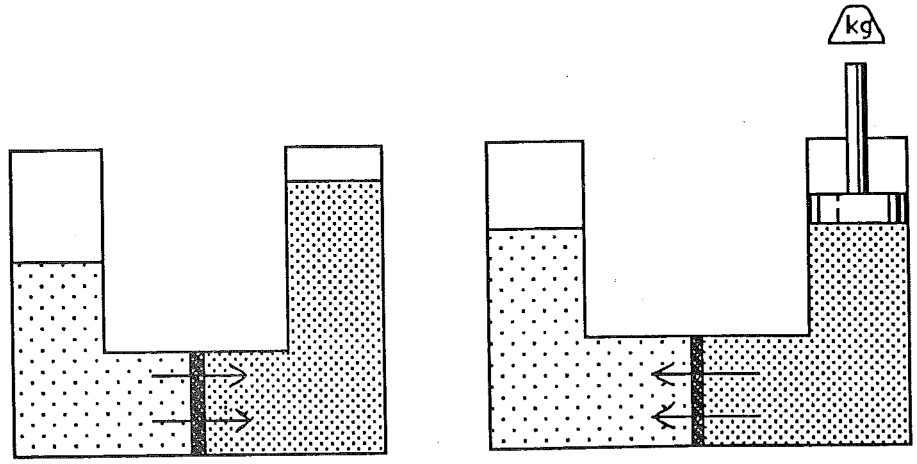
TDS	1500 mg/L	maximum
Fluoride	2.2 mg/L	"
Nitrate	100 mg/L	"

TDS (Total Dissolved Solids) is seen as the major concern (Walker 1988). Other criteria are likely to be satisfied by the use of a desalination device if used to reduce salinity (the major contributor to TDS).

Quantities of drinking water of 10 L/d per person is considered an acceptable minimum. For a community of 50 to100 people, this would require up to 1 cubic metre of drinking water to meet the standard.

REVERSE OSMOSIS

The discussion of Reverse Osmosis should commence with a description of Osmosis, a simple dilution process common to many biological systems. Osmosis occurs spontaneously when a semi-permeable membrane separates a dilute solution from a more concentrated one. The membrane is more permeable to the solvent than the solute. The dilute solution has a higher chemical potential than the concentrated solution and so solvent is drawn through the membrane under the chemical potential gradient from the less concentrated to the more concentrated solution.



OSMOSIS REVERSE OSMOSIS

Figure 1.

Reverse osmosis occurs when pressure is applied to the concentrated solution and the solute is forced through the membrane leaving an even more concentrated solution behind (Figure 1).

Because the concentration of the salt solution would build up far too high in the system shown above, feed water is actually forced across the membrane and only a small portion is allowed to pass through the membrane to be purified. This greatly prolongs membrane life and reduces maintenance. In the Spiral Wound configuration, two sheets of membrane are joined to form an envelope with a plastic channel cloth inside. The whole envelope is then wound up and inserted in a tubular cell. Feedwater is fed axially along the membrane, with the permeate passing into the envelope and collected through a central plastic tube (Figure 2).

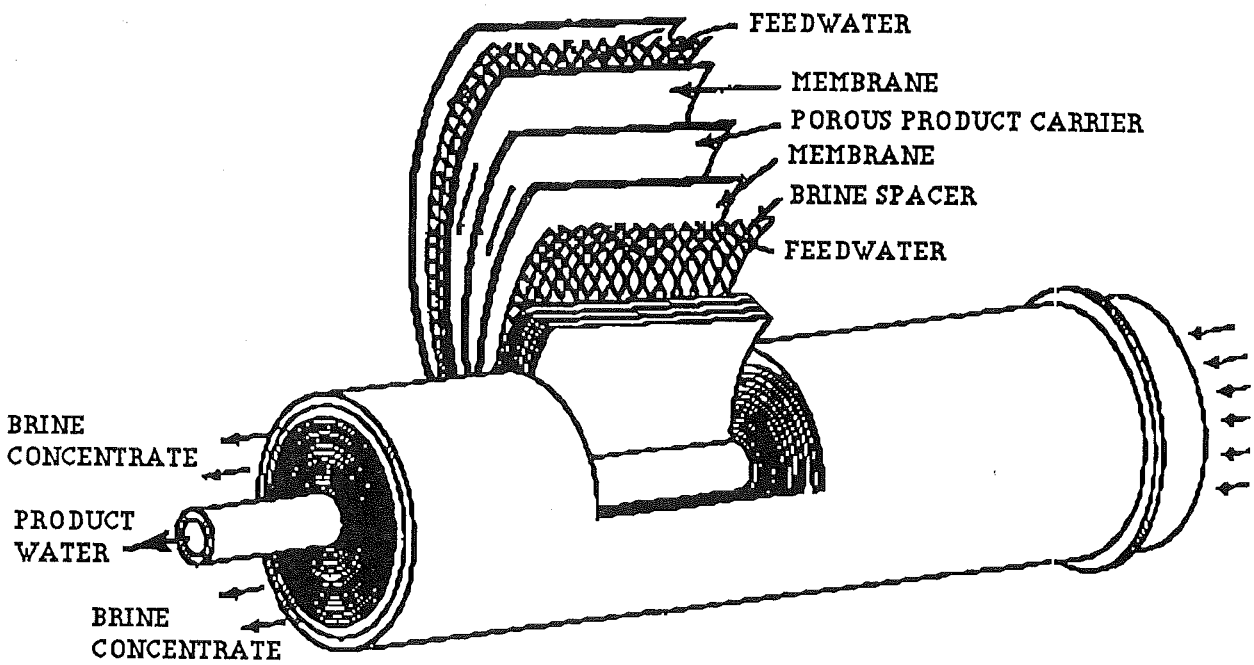


Figure 2. The Spiral Wound Membrane (After Buros 1987)

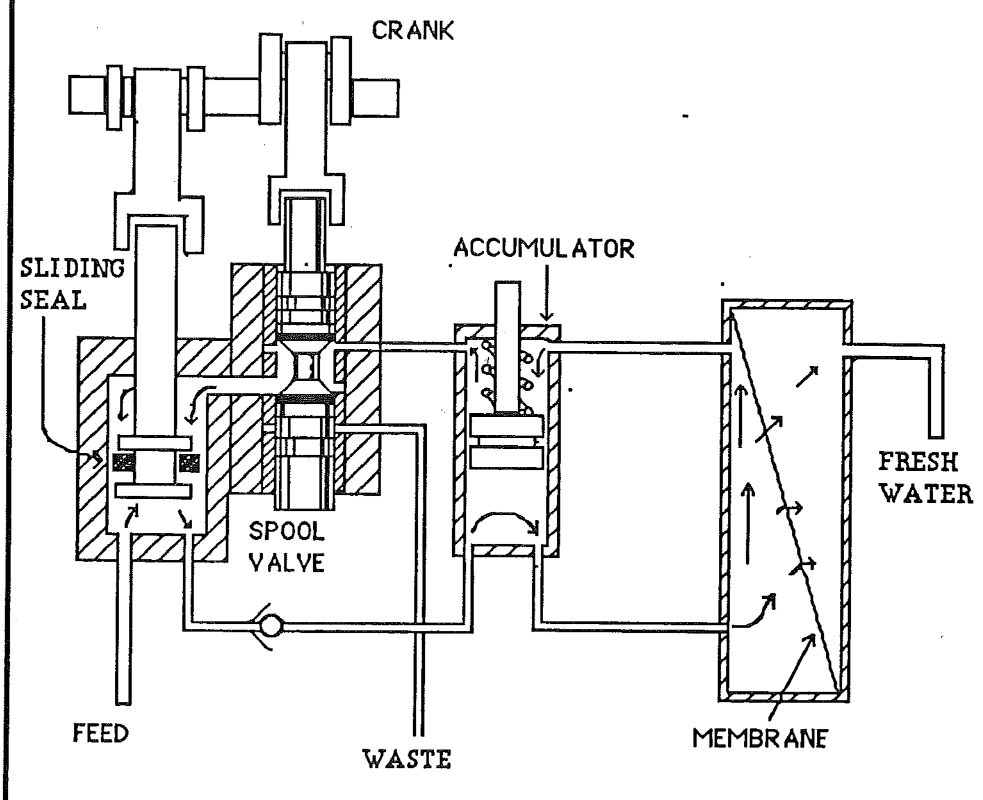
New low pressure spiral wound membranes have recently been introduced which reduce operating pressure to one quarter of that previously needed, and accordingly, one quarter of the power previously needed.

SOLAR POWERED REVERSE OSMOSIS

The use of solar power is increasingly seen as an appropriate technology for remote areas. It is clean, quiet, maintenance free, reliable and has a life expectancy exceeding 10 years (Arbon and Nielson 1987). Used extensively throughout Australias remote areas for telecommunications and increasingly for water pumping, its reputation and general acceptance are increasing. It is particularly favoured in regions which experience wind droughts or fickle winds where a windmill would be unreliable and its power production is matched to water demand. Diesel generators or diesel pumps require regular maintenance and repair, the expertise for which is not necessarily available in remote areas. Added to this is the constant demand for fuel. The only adverse factor affecting the use of solar power is its cost. Photovoltaic systems currently cost about $10 per peak watt, a unit which is often used in the literature but has very little meaning. It reflects only the initial capital investment and bears no relationship to meaningful values such as dollars per kJ or dollars per kL. A 100W PV array costs $1000 but may give 15 years maintenance free service. Of reliable proven solar desalination devices, only reverse osmosis and distillation can be considered as appropriate to remote communities.

Even with the advent of low pressure membranes, reverse osmosis normally needs quite a few solar panels to power it. For example, our optimum one cubic metre per day unit would require ten 50W solar panels ($5000 worth).

It has been apparent for some time that a great deal of energy is wasted in the reject stream which may represent 90% of the total water flow. The small unit we have tested channels this waste water (still pressurised) to the back of the pump piston thus assisting the motor in pumping. This unit uses about one fifth of the power it would otherwise need and allows its easy coupling to one solar panel. Other available systems use the same principle, for example the Seagold Unit (Figure 3).



SEAGOLD DESIGN SHOWING FLIPPING PUMP SEAL
AND HYDRAULIC ACCUMULATOR
(Patent US 44288326)

Figure 3.

PERFORMANCE TESTS ON 'POWERSURVIVOR' DESALINATOR

The little Powersurvivor has been directly coupled to a 55W (nominal) BP solar panel mounted on a Sundog solar tracker. The winter results are somewhat inconclusive but on sunny days, over six hours of near optimum production of 6 litres per hour was achieved with minimum salt rejection of 95%, well in excess of requirements (Figure 4). Using the average insolation data (Roy and Miller 1980) we can extrapolate this to summer conditions in Perth. The useful pumping starts at about 200Wm-2 insolation, which in summer would cover over ten hours (Figure 5). Using the 'hours of bright sunshine' data from the Commonwealth Bureau of Meteorology, it can be seen that in October, the critical month in the central north of the State, most areas likely to suffer from brackish bores also receive at least ten hours of bright sunshine per day (Legge 1987). Accordingly, production in these areas is tentatively predicted at 60 litres per day, enough for a small family group.

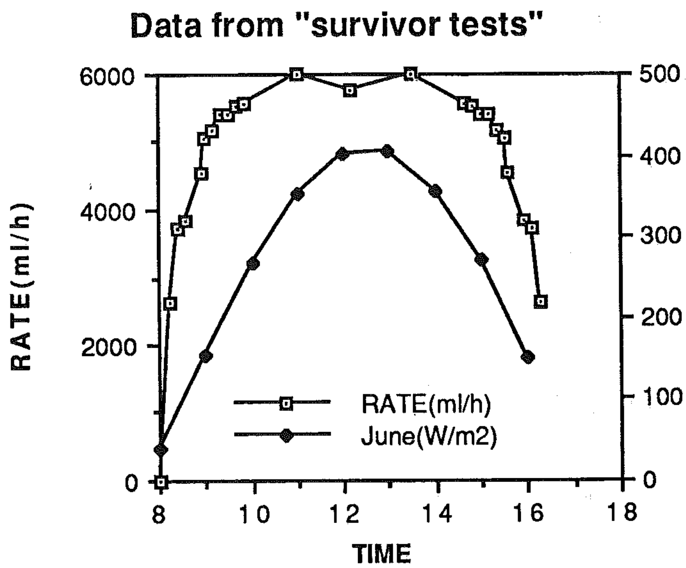


Figure 4. Product Flow Against Global Insolation

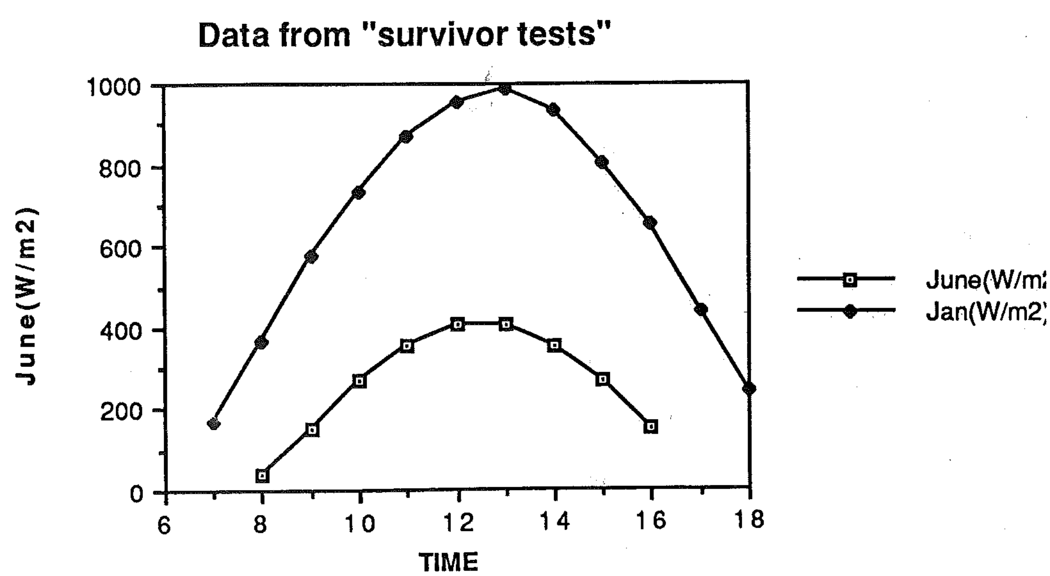


Figure 5.
Comparison of January and June Average Global Insolation

APPROPRIATE TECHNOLOGY ASSESSMENT

The Powersurvivor is designed as a seawater desalinator for yachts and accordingly does not use a low pressure membrane. Its power consumption is therefore higher than necessary for brackish water treatment but this is compensated for by its versatility, being able to treat water of any salinity. For a larger unit capable of supporting a small community it would need to be optimised on the feed water quality and a low pressure membrane would almost certainly be chosen. Maintaining the low recovery ratio would assist in keeping maintenance to a minimum.

The major concern regarding the appropriateness of this, and larger units available, is the difficulty in servicing. While individual components of these units are not particularly sophisticated or rare, they are assembled in a way to improve performance and marketability, engineering elegance at the expense perhaps of easy fault analysis and repair. In the context of remote localities it is probable preferably to keep the components separate and modular, also reducing the cost involved. This is not a criticism of the unit tested which was, after all, designed for a different environment.

The other facet to be considered is that the components should be as standard as possible so that parts are readily available. Full size membranes should not pose a problem in this regard, neither should standard O-rings and seals, the components most likely to require replacement.

DESIGN AND DEVELOPMENT OF A 1M^3 DESALINATOR FOR REMOTE COMMUNITIES

The Remote Area Development Group at Murdoch University has been developing a solar powered reverse osmosis desalinator for remote communities which will be capable of producing up to one cubic meter of fresh water per day from the power of two solar panels. While the cost of solar panel demands that a high efficiency must be attained, we cannot sacrifice reliability and serviceability to attain it. To this end, the use of batteries and electronic controllers has been avoided. Simple construction from PVC pipe and stock fittings and a modular design allow easy repair and servicing, while a variable recovery ratio allows the system to be tailored to individual feedwater quality, thus optimising production.

CONCLUSION

The commercially available desalination unit is versatile, compact, adapts well to solar power and has extremely good salt rejection characteristics. It is, however, quite expensive and discouraging if not difficult to repair. Its 60 litres per day capacity limits its use to a small group, bearing in mind that the extremely good quality water could be mixed with some brackish water depending on its salinity to bulk this out a little. Larger units which feature recovery of energy appear to be very complex and may have difficulty meeting the appropriate technology criteria.

Based on the available data, a larger machine capable of producing one cubic metre per day (ten hours) and equipped with energy recovery and low pressure membranes should be able to run off two 55W solar panels.

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