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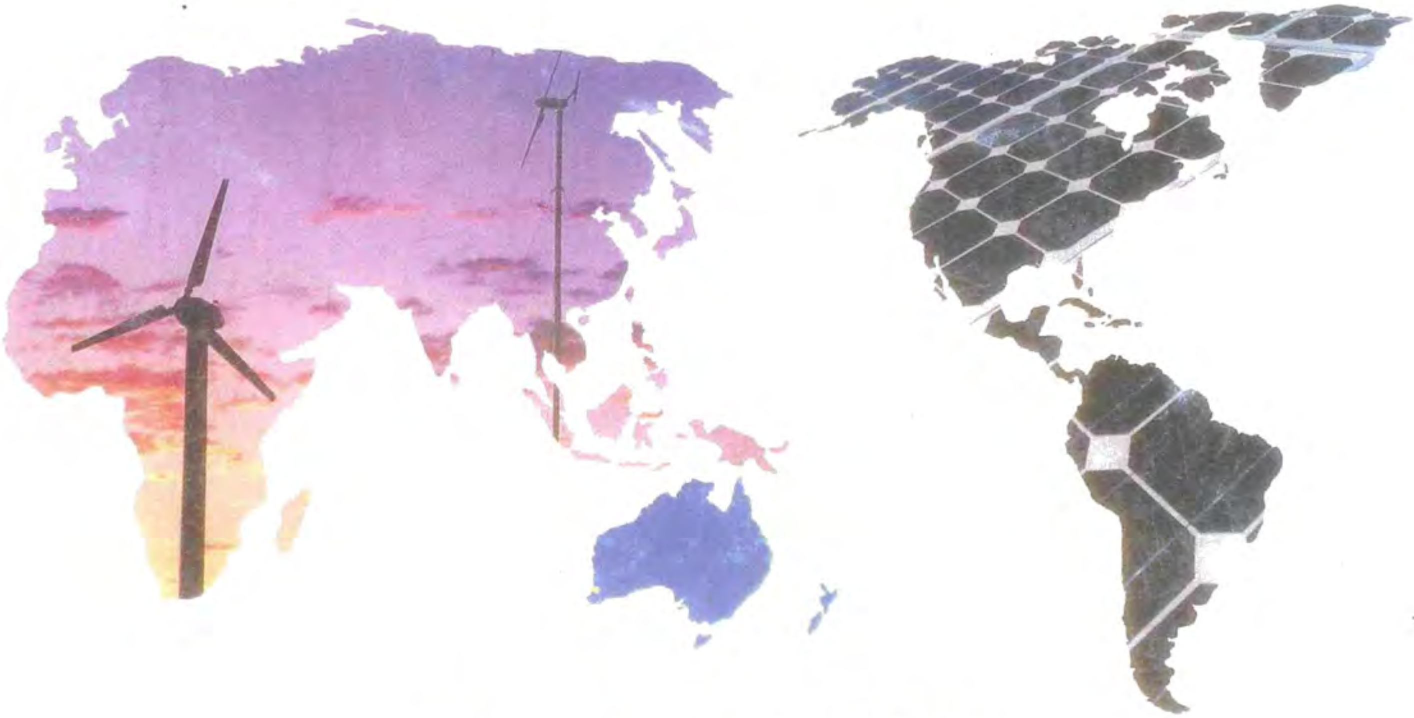

27 June - 4 July 2001
Murdoch University
Perth, Western Australia

Hosted by

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Innovative Solar-Powered Village Potable Water Supply

Kuruvilla Mathew[1], Stewart Dallas[2], Goen Ho[3] & Martin Anda[4]
Remote Area Developments Group, Institute for Environmental Science,
Murdoch University, Western Australia 6150
Email mathew@essun1.murdoch.edu.au

ABSTRACT

The Remote Area Developments Group (RADG) at Murdoch University in collaboration with local manufacturers Venco Products Pty Ltd and Solar Energy Systems Pty Ltd have developed a self-contained water supply and treatment system which is entirely solar-powered. The system is currently undergoing on-site trials at RADG's *Environmental Technology Centre* and is proposed for field trials in a remote Aboriginal community in Western Australia. RADG has been involved in the research and development of appropriate water supply and treatment systems units suitable for remote areas for over ten years. Research carried out by the group while working in remote Aboriginal communities in the late 1980's resulted in development of production prototype with industry partner Venco Products of the *Solarflow* – a solar-powered reverse osmosis desalination unit. The most recent work has seen the *Solarflow* become integrated with a locally designed and manufactured water pumping system, which is also solar-powered. Most remote Aboriginal communities rely on groundwater for their potable water supplies, however, this is a source which is often highly mineralised and in excess of the recommended drinking water quality guidelines for long term human consumption. The proposed installation at a community in the central lands is able to demonstrate a self-contained, solar powered water supply system which provides 400 litres/day of high quality, desalinated drinking water, an amount of water sufficient for up to 40 people. A system capable of meeting the requirements of larger communities of up to 150 people which can provide 1500 litre/day is currently in the prototype stage and under going performance monitoring before entering commercial production. The project can be linked to training programs in the area and will also be accessible by surrounding communities. This paper will describe the findings to date and the areas where further research is indicated.

BACKGROUND

The need for potable water in remote areas of Western Australia is widely known with many communities in rural areas suffering from scarce and often marginal quality drinking water resources. This is particularly evident in arid areas of Western Australia where rainfall and surface waters are limited and groundwater often contains high levels of salinity (3000 - 6000 ppm) and other contaminants (biological, chemical and aesthetic) (8). The deleterious health effects associated with prolonged consumption of highly mineralised drinking water are well documented and include kidney and gastric disorders (13). In particular such health problems due to inadequate quality drinking water in remote Aboriginal communities are prevalent (15). Significantly over 60% of Aboriginal communities rely on groundwater for their water supply with over an estimated 25% of these bores exceeding the salinity guidelines (14). Water for human consumption is required to meet the National Health and Medical Research Council Guidelines for Drinking Water Quality (13) and yet this is often not achieved in many remote communities.

This situation led to the investigation of appropriate technologies suitable for small-scale desalination in such communities. In cooperation with G.P. and G.F. Hill Pty Ltd as the industrial partner, the reverse osmosis *Solarflow* unit was developed by the Remote Area Developments Group (RADG). Due to portability, low maintenance and an output which matches demand, solar power was selected. This unit is capable of producing up to 400 l/day from brackish water of up to 5000 ppm total salinity from a 120 watt photovoltaic array. A larger 1500 l/day unit is currently undergoing pre-production trials.

The 400 litre/day version has two fixed recovery ratio options of 16% or 25% (Solarflow 40016 and Solarflow 40025). It has been designed to operate from a two panel photovoltaic array with built in maximiser to keep the solar panels at their optimum voltage of 30 volts. Efficacy can be improved by as much as 60 percent with the use of a solar tracker (7). The solar panels power a DC motor coupled to a high quality industrial gearbox which is capable of providing sufficient torque to run the unit even at very low power inputs. The efficiency of the unit is also greatly enhanced by the innovative energy-recovery system which allows the unit to operate with the minimum number of solar panels: the high pressure reject water is returned to the back of the piston to reduce the load on motor and gearbox, before being exhausted to waste.

The unit has recently been commercialised with twenty units presently in operation through Australia and South East Asia. The unit has won the Innovation category of the Western Australian Energy Efficiency Awards. The Alternative Energy Development Board (AEDB) of Western Australia has also provided funding for the current research and development of this project.

To date, the performance of the units placed in the field has been satisfactory, maintaining production rates and product quality often with irregular maintenance. This paper will present the findings of data from field situations, discuss the proposed central lands installation, and describe the areas where further research is indicated.

RESEARCH INTO A SOLAR-POWERED RO DESALINATION UNIT

Research on the *Solarflow* unit has focussed on photovoltaics as the most appropriate power supply and reverse osmosis as the desalination technique (7). Specifically it was necessary that the unit be simple, easy to service, robust, compatible with energy recovery and of low cost. Indeed many of the approaches taken were concessions to the range of appropriate technology parameters which were paramount for remote community application (1, 18). For example, the initial choice of low-speed double-acting simplex pumps were ultimately substituted with an integrated single acting pump to further reduce complexity (7). Similarly there are economies to be had in maximising recovery ratios, however, this in turn was not deemed to be of greater significance than the need to avoid pretreatment systems. It was reasoned that the energy recovery system would make this economical. Throughout the research and development to date, many such compromises were made to achieve a balance in the final product.

Typical energy consumption figures for reverse osmosis of brackish water with energy recovery vary from 0.5 to 2.5 kWh/m^3 although this data has been determined predominantly from large-scale systems (3, 6, 7).

Solar power is generally considered to be the best energy source for powering desalination plants in remote and arid regions (3). There are numerous ways however by which the energy can be harnessed and redistributed, such as battery storage, inverters and grid connection all of which may add to the complexity and losses of the overall system (17). With robustness and simplicity paramount, the Solarflow was ultimately configured to run directly from photovoltaic panels with the load thereby being matched to the variable solar supply (7). It was necessary however to incorporate an effective energy recovery system so as to reduce the energy required and hence reduce both the size and cost of the photovoltaic arrays. This led to the incorporation of a 'flow-regulated' approach to energy recovery as this maintains the set recovery ratio regardless of insolation levels (power input) and starts and stops automatically at sunrise and sunset.

DEVELOPMENT OF THE *SOLARFLOW* UNITS

Development of the complete unit took place over six years and resulted in four prototypes being built during this time (Mark I - Mark IV). It was at the end of development of the Mark II prototype that industry partner G.P. and G.F. Hill Pty Ltd became involved in the project and which led to several engineering and manufacturing improvements to the unit. Most significantly was the re-configuration from a two-cylinder to a one-cylinder system. From a manufacturing point of view this simplifies construction, improves modularity and reduces the cost of the unit. The single cylinder configuration was also favoured because of the ability to minimise parts since all valves are incorporated into the pump assembly. This makes field servicing by untrained personnel straightforward (10). A single cylinder is not ideal, however, for extracting maximum power from photovoltaic arrays as it gives large flow and pressure fluctuations and corresponding peaks and troughs in power demand. It was also considered likely that a single cylinder configuration would increase concentration polarisation and the risk of membrane scaling due to the period where flow is stalled. Membrane fouling and scaling are widely reported as being the main drawback as well as the least understood phenomena of reverse osmosis systems (4, 11). As described in the following section it appears that such concerns are unfounded.

SUMMARY OF FIELD TRIALS

Four sites of differing nature where field data on the *Solarflow* unit has been obtained are presented below. They represent two local sites - where one is a surface water source, a remote but monitored location in Central Australia and a site in Indonesia.

Table 1. Summary of Field Trials

Location	Duration	Activities	Outcomes	Recommendation
Environmental Technology Centre and Venco factory, Perth, WA	1995 ongoing	24 h/d bench testing at factory before ETC; 1500 unit with 6 and 8 panel PV array on 16% recovery ratio.	Main pump cylinder cracking and seal failure on piston rod gland detected in bench trials; 1069 and 1235 l/d achieved with new power maximiser.	Use solar tracker to gain additional 40% and 20% output req'd; 25% recovery ratio will then exceed 1,500 l/d.
Gidgegannup, WA	Several months	Feed from creek at 2,000 – 3,000 ppm salinity.	Fouling of 20 and 5 micron pre-filters by algae reqd use of sand filter pre-treatment.	Use sand filter as pretreatment on feed waters with bio-contamination.

Centre for Appropriate Technology, Alice Springs, NT	1997 4 weeks	Feed water from both AS at 860 uS/cm and Fregon at 2180 uS/cm to 400 unit.	350 l/d with no cloud from AS feed; 300 l/d or 20 l/amp hr (1.2 kWh/1000 l of product water) from Fregon feed; seal and piston faults since eliminated.	A sensible balance needs to be achieved between long-term trials and commercialisation.
Java, Indonesia		4 units using surface water feed.	Biological fouling of pre-filters.	Regular replacement of prefilters necessary or additional sand filter.

To date, the 21 in-field models have performed for over 12 months with only irregular maintenance, and have maintained production rates and quality. No problems have been reported with the power source (photovoltaic panels) either in terms of maintenance, performance, service or vandalism. The period between membrane replacement was estimated at the design stage to be in the order of two to four years depending upon the feedwater quality and while further time needs to elapse before this can be confirmed, such a period appears to be achievable.

The *Solarflow* operating on creek water at the Gidgeeganup site is the first unit to be run with a surface water feed source and has demonstrated the increased complexity of treating surface water as compared to ground water via reverse osmosis. The Indonesian feedback also indicates algae and biological buildup on the pre-filters from a groundwater source. Further trialing of sandfilters as an effective low-cost pretreatment system is required. A small-scale sand filter system, the *Environ 30* supplied by QED Australia Pty Ltd, is used to treat bore water prior to drinking at the *Environmental Technology Centre* and could be used as the pretreatment unit.

The units being monitored at the ETC have also performed according to specification although further trials on the 1500 l/day unit incorporating a solar tracker for the eight panel array will continue. See Figure 1. The ETC site has demonstrated the need for simulated long-term testing of units in a field situation as it enables unit modifications to be made to the model prior to full-scale marketing. The problems encountered whilst under trial at the ETC described previously were able to be remedied through relatively inexpensive material and design changes. Whereas, the cost penalty associated with 'discovery' of these problems whilst in operation in remote and overseas locations would have been significant. The situation described at the Alice Springs site highlights the need for actual field testing prior to full-scale production and provides an insight into what could have occurred had there been premature placement of units in the field. Consequently, the RO unit can now be confidently integrated into the new Village Potable Water Supply system and commercialised with the industry partners.

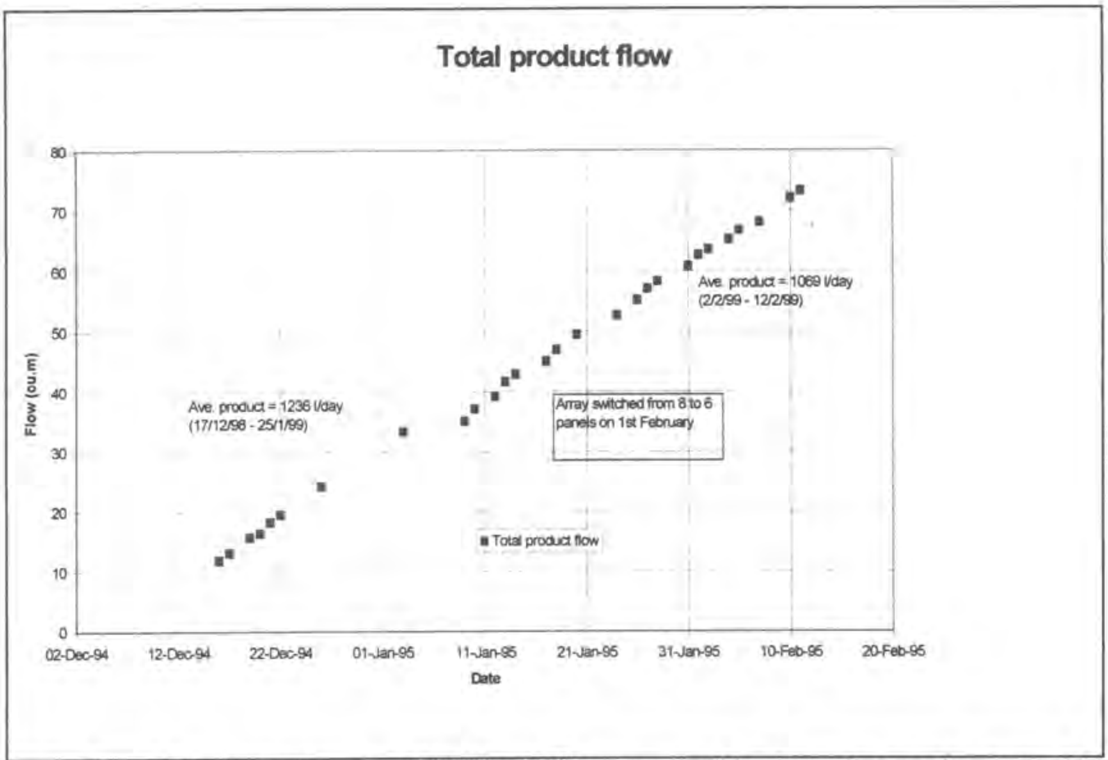

Figure 1. Product volumes on 1500 l/day (16% recovery ratio) unit running on solar power at ETC

COMMERCIALISATION OF THE SOLARFLOW UNITS

The partnership between Murdoch University and GP & GF Hill Pty Ltd (Venco Products – manufacturer of the Solarflow units) has been expended to include Solar Energy Systems (SES). SES are a commercial manufacturer & distributor of solar powered water pumping and power systems incorporating unique components including (amongst other things) the Sun Tracer tracker, Poly Piston Pump and Power Maximiser (maximum power point tracker). This expanded partnership has allowed the development and commercialisation of a complete integrated village water supply system that treats water to potable quality, which includes all the latter components from SES. The system can also be configured as a stock water supply and treatment system. The total 1,500 litres/day system was installed at the Environmental Technology Centre for commercial demonstration purposes as well as ongoing trials. The system was inaugurated by the WA Minister for Water Resources on October 3, 1999.

Component costs of the "Total Village Potable Water Supply" system are listed in Table 2.

Table 2. Component costs of total village potable water supply system

Component	Sub component	Cost ($)
250 W Solar Stock Water Pump	4 x 64 W Canon Unisolar PV panels; F2 sun tracer; Custom-built power maximiser; Tall pump drive with 540 W motor; Poly Piston Pump.	$6,460
Solarflow 400 l/d reverse osmosis unit		$6,188
Water tanks and tank frame		$3,300
Spare parts – pump & sun tracer	Stuffing box, nylon rod, foot valve,, seals and piston for Poly Piston Pump ($220); Spare DC motor & brushes $685); Gearbox oil, grease and grease gun ($100); Battery, electronics andsensor for sun tracer ($375); Power maximiser ($400); 2 x Canon Unisolar panels ($1,280).	$3,060
Spare parts – Solarflow	RO membrane ($639); 10 x 5 micron 10" filters (non-wash) ($100); 5 x 30 micron 10" filters (washable) ($85); Pump assembly ($1,930); Conductivity meter ($150); Pressure gauges ($32).	$2,936
Total		**$21,944**

PROPOSED DEMONSTRATION UNIT IN CENTRAL RESERVES

It is proposed to install a 400 litres/day complete system at a major Aboriginal community in the central lands region of Western Australia to enable community managers and residents from there and surrounding communities to evaluate the quality of system performance and the water for drinking purposes. Groundwater supplies to all of these communities are typically highly mineralised. Table 3 compares the chemical water quality from Perth mains supply (at Murdoch), ETC groundwater, and Warburton groundwater from 1999 samples.

Table 3: Physical - Chemical Analyses of Perth Mains, ETC Bore, Warburton Bore.

Loc'n	Al mg/l	Ca mg/l	Cl mg/l	E. Con mS/m	Fe mg/l	Hardness mg/l	Mg mg/l	Mn mg/l	TDS Calc mg/l	pH
Perth	0.13	3	53	23.5	0.20	24	4	0.02	130	6.8
ETC	0.16	4	78	38.8	0.36	55	11	<0.02	210	7.2
Warb.	<0.008		190		0.007	430		<0.002	970 TFS	7.73
NHMRC guide	0.1		250		0.3	60-200		0.5	500-1000	6.5-8.5
Max. for plant growth									1000	

As can be seen from Table 3, the drinking water supply at Warburton, like that of many communities in remote areas, is highly mineralised. While this level of calcium carbonate or TDS is not directly deleterious to human health, indirectly it can be. For a start, water with bad taste does not encourage drinking of the volumes of water ideal for better health. Ideally, one should drink around 2 litres/day but when involved with physical work in the hot outdoors this should be more like 5 litres/day. Moreover, the tendency for many people in remote indigenous communities is to add cordial to water with poor taste or to consume soft drinks instead [19]. This excessive consumption of sugar contributes to poor health and may lead to diabetes – a common problem in indigenous communities. Furthermore, highly mineralised water supply causes scaling in kettles, hot water systems, and the seals of toilet cisterns.

The provision of a second reticulated water supply from the *Solarflow* unit and dedicated for drinking purposes has the potential to make a major contribution to improved health in indigenous communities if this can encourage drinking greater volumes of fresh water. While it may not be feasible to service all households with one unit in a community as big as Warburton a unit could be installed at each key community facility, such as the school, clinic, store, office, college, where large numbers of people congregate and where a high quality drinking water supply would be appreciated and well-patronised. Alternatively, one unit could service each cluster of dwellings. Initially, one unit could be established at one community facility as a demonstration.

CONCLUSIONS

Performance of the *Solarflow* (400 l/day unit) to date has been in line with expectations in terms of low maintenance, minimal servicing requirements and treated water volumes. It is likely that this is a result of the many design and engineering concessions to appropriate technology parameters for remote area application. In order that more sites may have access to the unit, investigations into pretreatment and prefilter systems suitable for the *Solarflow* are underway (16). This will allow those sites which have feedwater that according to current knowledge should induce fouling, to be serviced. Any additional equipment required, however, to enhance the performance of the *Solarflow* unit will need to be developed according to the same guidelines that were paramount in the construction of the unit itself: simplicity, low cost, low maintenance and robustness.

The *Solarflow* is ready for application in most situations. The recent partnership with Solar Energy Systems Pty Ltd will allow the final stage of commercialisation to occur. This partnership has resulted in the integration of the Solarflow with the other components necessary for a total village potable water supply. It is now necessary to establish a series of demonstration sites for key market sectors such as remote indigenous communities, stock watering systems, remote homesteads, small island communities, and villages in developing countries.

ACKNOWLEDGEMENTS

We wish to acknowledge funding provided by the Alternative Energy Development Board of Western Australia (AEDB) and from the Department of Commerce and Trade (DCT) to the *Environmental Technology Centre* as part of the State Government's Centres of Excellence program. The support of GF and GP Hill Pty Ltd (Venco Products) and Solar Energy Systems Pty Ltd is gratefully acknowledged.

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1. Dr Kuruvilla Mathew, Research Fellow, Manager.
2. Stewart Dallas, Professional Officer, Manager, Environmental Technology Centre.
3. Assoc Prof Goen Ho, Director.
4. Dr Martin Anda, Research Fellow.