ELSEVIER

Desalination 179 (2005) 51–59

DESALINATION

www.elsevier.com/locate/desal

System design and performance testing of a hybrid membrane — photovoltaic desalination system

Laurent Masson[a,b], Bryce S. Richards[c], Andrea I. Schäfer[a]*

[a]*Environmental Engineering, University of Wollongong, Wollongong, NSW 2522, Australia*
Tel. +61 (2) 4221-3385; Fax +61 (2) 422- 4738; email: schaefer@uow.edu.au
[b]*ESIGEC, Université de Savoie, Le Bourget du Lac, 73376, France*
[c]*Centre of Excellence for Advanced Silicon Photovoltaics and Photonics, University of New South Wales Sydney, NSW 2052, Australia*

Received 3 December 2004; accepted 17 December 2004

Abstract

In some areas limited water resources combined with the fast growing population are leading to a crucial situation because of the increase in water demand. Besides, an estimated one billion people are living both without access to clean drinking water or electricity. Therefore, a stand alone photovoltaic-power based hybrid membrane desalination prototype has been designed to meet this challenge. Several parameters were examined in order to optimise the system performance, including i) feed water salt concentration, ii) operating pressure, iii) system recovery, iv) specific energy consumption (SEC) and v) salt retention. With a SEC varying from 2.2 to 7.7 kWh.m^{-3}, the installation designed for remote villages is able to produce up to 1.2 m^{3}.d^{-1}.

Keywords: Desalination; Reverse osmosis; Nanofiltration; Photovoltaic; Remote community water supply

1. Introduction

The lack of water resources and safe drinking water scarcity has been recognized and analysed by different international organisations such as the World Health Organisation or the World Bank [1]. The problem is being further deteriorated by the pollution of the rivers and lakes from industrial waste and sewage discharge. On a global scale, man-made pollution of natural resources of water is becoming the single largest cause for the fresh water shortage [2].

Further, the lack of adequate treatment facilities leads to adverse health effects for local community members especially in rural and remote areas. While the remote conditions make it rather

*Corresponding author.

Presented at the conference on Membranes in Drinking and Industrial Water Production, L'Aquila, Italy, 15–17 November 2004. Organized by the European Desalination Society.

doi:10.1016/j.desal.2004.12.022

difficult to operate and maintain conventional treatment technology, its application is often limited by the availability of electricity, with many rural areas having no access to a national electricity grid. Therefore, it is widely recognised that water filtration methods powered by renewable energy sources are needed around the world [3].

In response to this need, several photovoltaic (PV) powered reverse osmosis (RO) and other such water desalination and filtration systems do exist to tackle water shortages [4–12]. The adaptation of such systems to remote community use, where maintenance facilities are generally not available, is largely a question of system design.

This led to the development of a photovoltaic-powered reverse osmosis desalination unit, called ROSI (Reverse Osmosis Solar Installation), which is designed to deliver a production flow of 1,000 L/d of clean drinking water from various ground or surface water sources to meet the demand of a small remote community.

2. Review of existing PV powered membrane filtration systems

PV-powered water pumping systems are extremely reliable, and are able to provide water in remote areas for the lowest costs [5]. Consequently, many examples of photovoltaic powered reverse osmosis (PV-RO) treatment systems can be found in the literature. The majority of PV-RO systems have been designed to operate at high pressures (> 40 bar) in order to desalinate seawater, often for off-shore applications. An overview of PV-RO systems reported in the literature, including various operating parameters and system performance is shown in Table 1.

The limitation of many systems is membrane fouling which needs to be addressed with appropriate pre-treatment methods. To date such pretreatment as well as long term system maintenance methodologies have not been fully explored.

3. System design

3.1. Main concept and history of the project

The basic design concept for the reverse osmosis solar installation (ROSI) is to use a photovoltaic powered source to power pumps required to produce the driving force for the hybrid membrane process to produce potable water from a variety of possible water sources (from high turbidity surface waters to high salinity brackish water). For the various prototypes developed an operating window is determined where SEC is

Table 1
Overview of PV-RO units sorted by PV array size (adapted from [6])

Location	TDS conc. ($g.L^{-1}$)	$P_{operate}$ (bar)	Salt retention (%)	Recovery (%)	Clean water ($m^3.d^{-1}$)	SEC ($kW.h.m^{-3}$)
Portugal	2–5	4	90	2	0.02	25.6
Australia	3.5	4–10	92	10	0.1	8
Australia	5	—	—	16 or 25	0.4	—
Canada	33	34–35	97–99	14	0.85	4.0
Australia	—	—	88	—	0.4–1.0	4.0–5.8
UK	40	40–60	—	—	3†	3.5†
Mexico	Brackish	40	—	—	0.7–1.4	4.0–6.9
Oman	1	12	96.6	65–70	5	2.3
Israel	4	4–16	98	50	3	—
Spain	35	45–70	>98.5	—	>0.8	15–16

†Simulated results