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7-18-2006

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Clark C. K. Liu
University of Hawaii at Manoa

Krispin Fernandes
University of Hawaii at Manoa

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Clark C.K. Liu and *Krispin Fernandes*
University of Hawaii at Manoa
Honolulu, HI 96822 USA

Extended Abstract

The principal objective of this Research project was to develop a simple cost-effective desalination system for Pacific islands and other remote coastal communities where both freshwater and electricity are in short supply.

Pacific islands fall into two general categories: large volcanic islands and low atoll islands. Perennial streams exist only in large volcanic islands where storage facilities are required to regulate highly variable rainfall distributions. Due to the high porosity of the ground, a surface water supply is almost non-existent in low atoll islands. The groundwater supply in Pacific islands generally occurs only in large volcanic islands as a basal water lens where freshwater floats on top of seawater. Water in the transition zone, which separates freshwater from seawater in this water lens, is brackish (Figure 1). The high salinity of the brackish water makes this groundwater supply unsuitable as a freshwater source. Over-pumping of coastal groundwater, which causes an expansion of the transition zone as well as a declination of the water table, often causes more freshwater to become brackish (Liu, 2006). As for atoll islands, rainfall readily mix with the underlying saltwater, such that only brackish groundwater occurs.

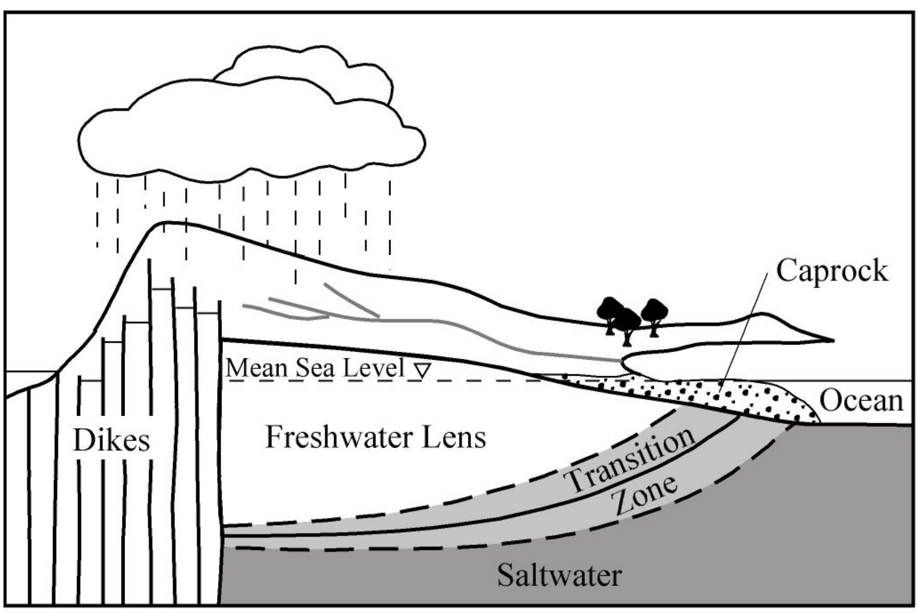

Figure 1 Brackish water in the transition zone of a Hawaii basal water lens

Pacific islands are rich in renewable energy - constant trade winds and strong solar radiation. Therefore, brackish water desalination driven by renewable energy is one of the viable water supply alternatives. Recent advances in membrane technology, especially in the area of ultra-low-pressure reverse osmosis (RO) membranes, make this alternative more attractive.

A preliminary testing system of wind- driven RO desalination was developed several years ago by University of Hawaii at Manoa. The system is located on Coconut Island, Oahu, Hawaii; the island is owned by University of Hawaii and is the home of its Hawaii Institute of Marine Biology. A series of field experiments were conducted using pre-mixed sodium chloride solution as the feedwater (Liu, et al., 2002). This system was later successfully applied for the removal of nitrogen from aqua cultural wastewater (Qin, et al., 2005)

This preliminary testing system was not ready for real-world application because it could not provide dual working pressure for feedwater pretreatment and for RO desalination. Also, the system was not entirely driven by renewable energy as the measuring instruments were operated by electricity.

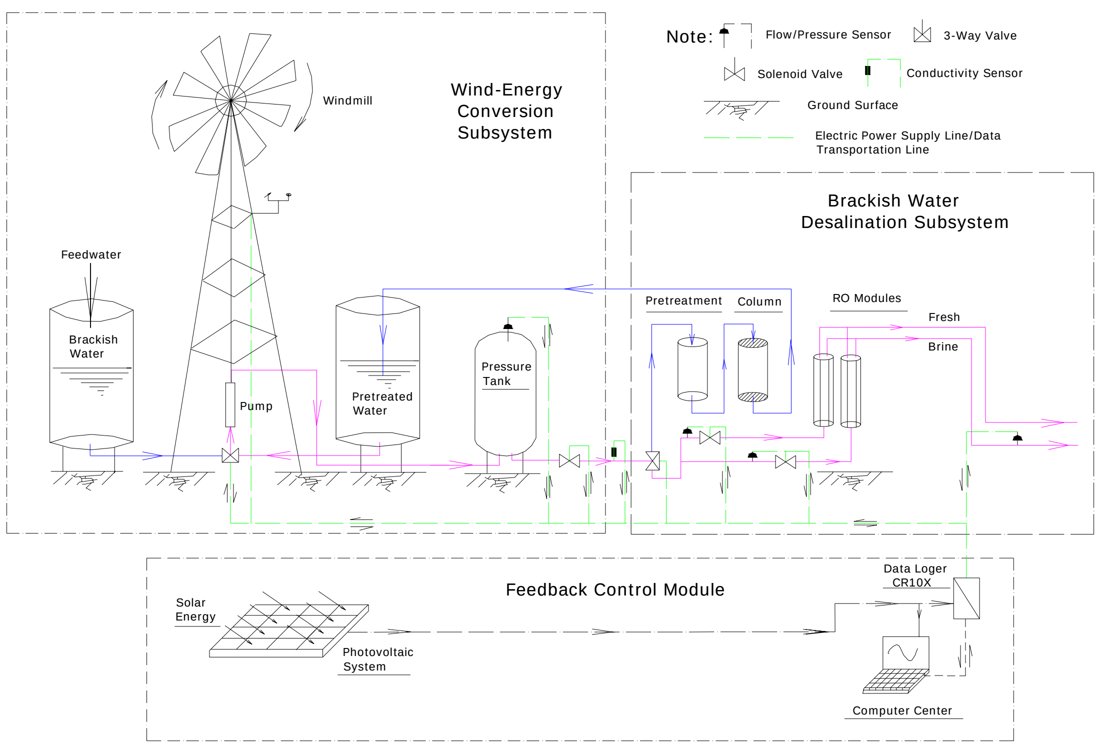

Figure 2 Wind-driven reverse osmosis desalination system and sub-systems

With funding support from US Bureau of Reclamation, more research efforts were made during the last two years to modify the original testing system for real world application. As shown in Figure 2, the modified system consists of (a) a wind-driven pumping subsystem and (b) a pressure-driven membrane processing subsystem. A feedback control module integrates and operates the two subsystems. The wind- driven pumping subsystem can raise the feedwater pressure to two different levels for pretreatment and for RO desalination. The modified system is operated entirely by renewable energy – using wind power to drive an RO desalination process and using solar photovoltaic (PV) energy to drive system instruments for data acquisition and control.

Results of field experiments with modified system indicated that the salinity of the brackish feedwater, in terms of total dissolved solids, was reduced from over 3,000 mg/L to below 200 mg/L. The overall average rejection rate was about 94%, and the average recovery ratio was about 25%.

A mathematical of this wind-driven desalination was developed based on energy and mass conservation principles. It was calibrated based on experimental data.
The calibrated model simulates the system response to varying input conditions of wind speed and feed water salinity.

Fig 3 shows the simulated flow rate and salinity of permeate as a function of wind speed, with a constant feedwater salinity of 2,500 mg/l and a constant operating pressure of 620 kPa (90 psi).

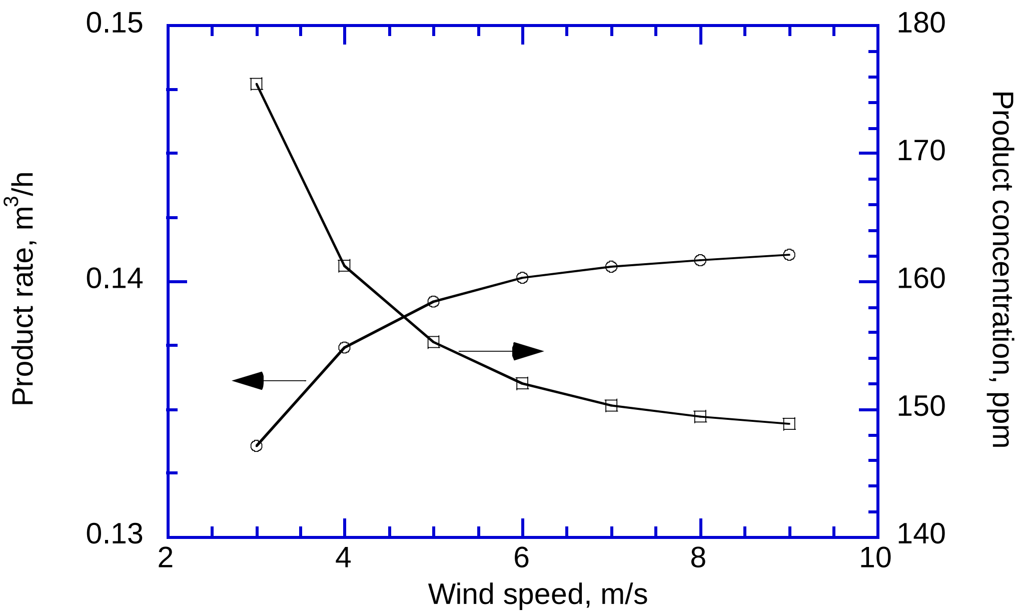

Figure 3 Modeling results with fixed operating pressure, p = 621 kPa and feedwater TDS concentration of 2500 ppm

A full-scale demonstration plant of renewable energy-driven RO desalination was designed and analyzed. This plant uses 20-ft windmills and 50-units of windmill/pump and membrane processing in parallel and in series (Figure 4). Cost analysis was conducted in terms of system cost, income, and system salvage value. Results of the cost analysis indicate that Freshwater can be produced for small island communities at a cost of $5.40 per 1,000 gallon.

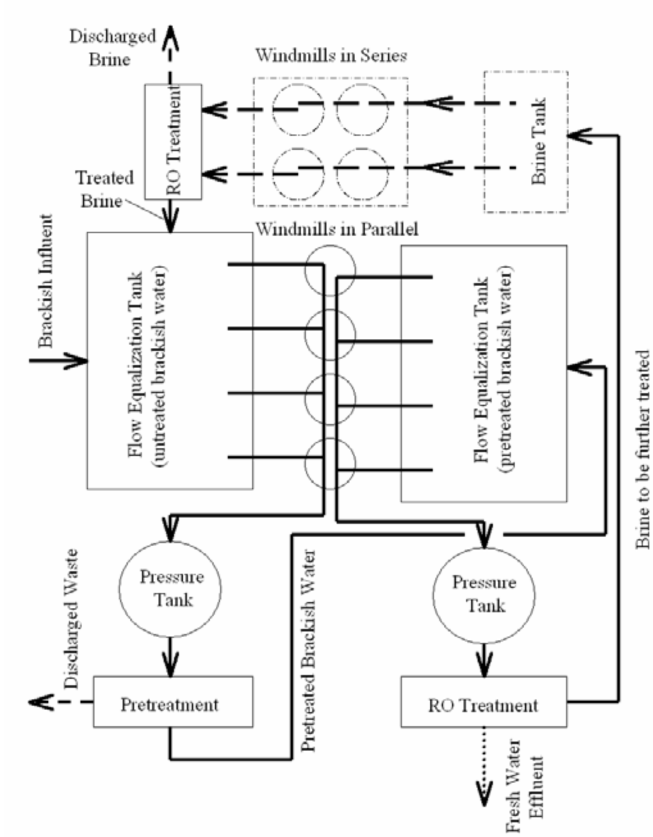

Figure 4 Schematic of a renewable-energy-driven RO desalination demonstration plant

References

1. Liu, C.C.K. Park, J. W., Migita, J. and Qin, G. 2002. Experiments of a Prototype Wind-driven Reverse Osmosis Desalination System with Feedback Control, *Journal of Desalination*, 150(3):277-287.
2. Liu, C.C.K. 2006. *Analytical groundwater flow and transport modeling for the estimation of the sustainable yield of Pearl Harbor aquifer*, Project Report PR-2006-06, Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii.
3. Qin, G., Liu, C.C.K., Richman, N.H. and Moncur, J.E.T. 2005.Aquaculture Wastewater Treatment and Reuse by Wind-driven Reverse Osmosis Membrane Technology: A Pilot Study on Coconut Island, Hawaii, *Journal of Aquacultural Engineering*, 32:365-378.

Author contact information:

Clark C.K. Liu, Ph.D., P.E., Professor and Researcher
Water Resources Research Center
University of Hawaii at Manoa
Honolulu, HI 96822 USA(808) 956-7658
clarkliu@hawaii.edu