Brackish Water Desalination Through Eolic Reverse Osmosis for Rural Communities

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Abstract

Many rural areas located in arid or semi arid climates depend on ground water as the only source of fresh water. Unfortunately, many of these sources present high levels of toxic and non-toxic elements like sodium chloride, sodium sulfate, arsenic and fluoride. Reverse osmosis (RO) has become the standard way to desalinate small scale process. In many cases rural areas have a very low income leading to the abandoned of RO units because of lack of energy bills. This situation brought the objective to develop an eolic RO unit with lower operating cost. The specificobjectives of the project were **1)** To develop of an eolic energy buffer system to reduce pressure variation between the commercial eolic pump (wind mill) and the RO membrane unit. **2)** The installation and performance monitor of a pilot eolic RO unit under different wind conditions. 3) The evaluation of energy savings per m^3 of produced potable water. A commercial 16ft wind mill with a 3" piston from Aeromotor along with three 4" x 40" spiral wound membrane model SE4040CZH from Osmonics were selected and installed at an arsenic and fluoride underground water source with 897 ppm of total dissolved solids (TDS). An eolic energy buffer was designed and installed between the wind mill and the RO membranes. The eolic energy buffer controlled operating pressure at wind speeds from 0 to 40 km/hr. The buffer system was able to operate water pressure between 3.75 and 4.5 bar. The minimum wind speed that obtained the lowest operating pressure (3.75bar) was 10 km/hr with a water production of 45 l/day. The maximum useful wind speed was 18 km/hr with a maximum operating pressure of 4.5 bar and a maximum water production of 105 l/day. The pilot eolic RO averaged in a 12 month period a wind speed of 6.55 km/hr, and the regulate operating pressure was an average of 4.4 bar with an average water production of 30.8 l/day and 49 ppm of TDS. No external energy was needed in the desalination process aside from eolic energy. Energy savings for the pilot conditions were \$ 0.36 / m^3. The Eolic Energy Buffer System regulates inlet pressure at set point allowing commercial wind mills and reverse osmosis membranes to be connected and operate with regular maintenance. The Eolic Reverse Osmosis system represents a feasible, reliable and sustainable small scale desalination option for rural areas.

Introduction

Mexico has 23.46 % of its population living in rural areas, about 24 million people. According to the 2007 national water statistics, 10.8 % of the total population lack access to potable water must of them located in rural areas. Based on a Marginalization Index, where piped water is one of the criteria, 4.5 million people live in high degree of marginalization. Many of these communities are located in arid or semi arid regions where ground water represents the only source of water. Unfortunately, many of these sources present high levels of toxic and non-toxic elements like sodium chloride, sodium sulfate, arsenic and fluoride, making ground water non potable. Currently, 2,000,000 and 20,000,000 people are affected by high concentrations of arsenic and fluoride in their ground water source, respectively. Also many aquifers present high levels of dissolved solids, making underground water non potable. These elements like many others make ground water unacceptable for drinking purpose, according to Official Mexican Standard (NOM-127-SSA1-1994) and international potable water standards. The limit between freshwater and lightly brackish water is 1000 ppm of Total Dissolved Solids, according to the Official Mexican Standard. Figure No. 1 shows the concentration of total dissolved solids in Mexican ground water.

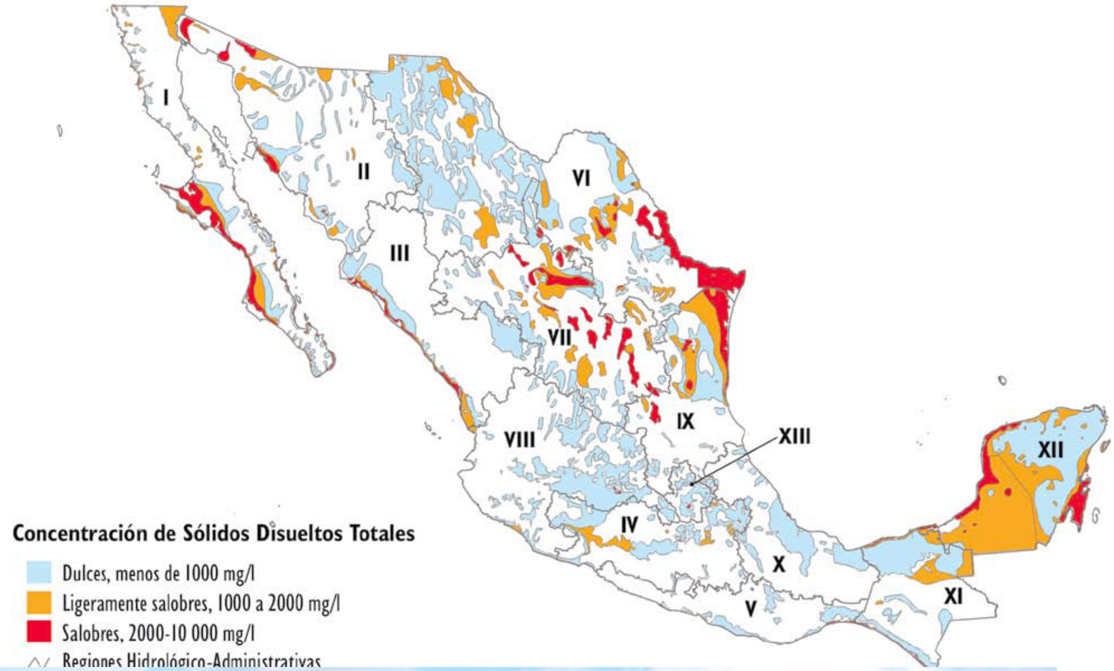

Figure No.1 Concentration of total dissolved solids in Mexican ground water

Reverse osmosis (RO) has become the standard way to eliminate dissolve solids in small scale process. RO investment costs have been reduced in the last 20 years to affordable levels even for rural areas; however, operating costs have increased in the past 20 years due to an increase energy cost. Mexican water authorities have had water policy to provide rural areas with the RO systems. These units provide enough water (12 – 20 liter / person-day) for the essentials. Although the community do not pay for the RO investment cost, they are responsible for the operating cost. Many rural areas have a very low income ($ 9.0 USD/ household-day) turning operating RO cost into unachievable responsibility. This situation leads to abandoned RO units or even results in no units at all. The general objective was to develop an eolic RO unit with a lower operating cost, compared to the standard electrical RO unit operating cost. The specific objectives of the project were; **1)** To develop of an eolic energy buffer system to reduce pressure variation between the commercial eolic pump (wind mill) and the RO membrane unit. **2)** To install and monitor performance of a pilot eolic RO unit under different wind conditions. **3)** To evaluate energy savings per m^3 of produced potable water.

Methodology

A typical 500 people rural community was selected for pilot purposes. The community (Figure No.2) is located central Mexico, Guanajuato well known arsenic and fluoride affected area. The community was initially evaluated in terms of drinking and cooking habits as well as external arsenic and fluoride exposed symptoms. No attempt was made to evaluate initial health status of the selected community. A proprietary conceptual system was developed and installed to joint a commercial wind mill with a commercial RO unit. A commercial 16ft wind mill with a 3" piston from Aeromotor along with three 4" x 40" spiral wound membrane model SE4040CZH from Osmonics were selected and installed at an arsenic and fluoride ground water source with 897 ppm of total dissolved solids (TDS). Wind speed, pressure, conductivity and flow rate sensors were installed to send data every 15 minutes using Advantage Pro 5, ADCON Telemetry. Pilot unit has been monitor during a 2 year period. To evaluate energy savings per m^3 of potable water produced, an electrical (commercial) RO system installed at Monterrey Mexico was evaluated to determine regular energy consumption at similar concentrations of total dissolved solids.

Figure No. 2 Selected Rural Community in Guanajuato, Mexico

Results

The eolic energy buffer controlled operating pressure at wind speeds from 0 to 40 km/hr as seen in Figure No. 3 and 4. The buffer system was able to operate water pressure between 3.75 and 4.5 bar. The minimum wind speed that obtained the lowest operating pressure (3.75bar) was 10 km/hr with a water production of 45 l/day. The maximum useful wind speed was 18 km/hr with a maximum operating pressure of 4.5 bar and a maximum water production of 105 l/day.

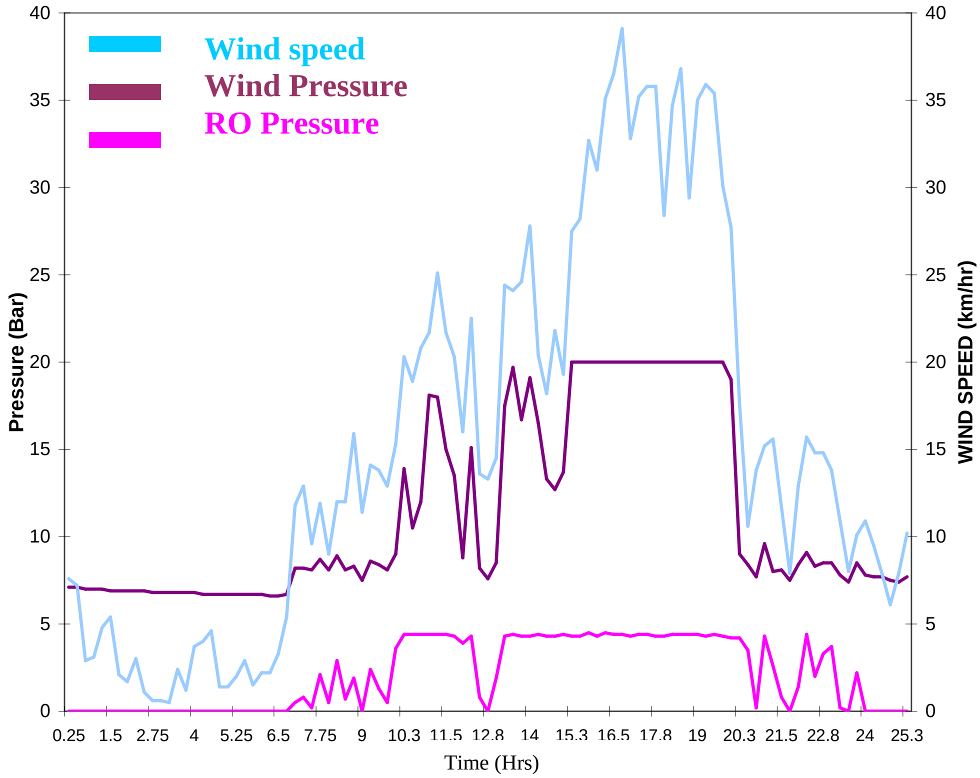

Figure No. 3 Wind speed, wind pressure and RO pressure during a 24 hr eolic reverse osmosis operating period.

Figure No. 4 Flow rate and permeate conductivity during a
24 hr eolic reverse osmosis operating period.

The pilot eolic RO averaged in a 12 month period a wind speed of 6.55 km/hr, and the average regulated RO pressure was 4.4 bar with an average water production of 30.8 l/hr and 49 ppm of TDS, as seen in Figure No. 5. No external energy was needed in the desalination process but eolic energy.

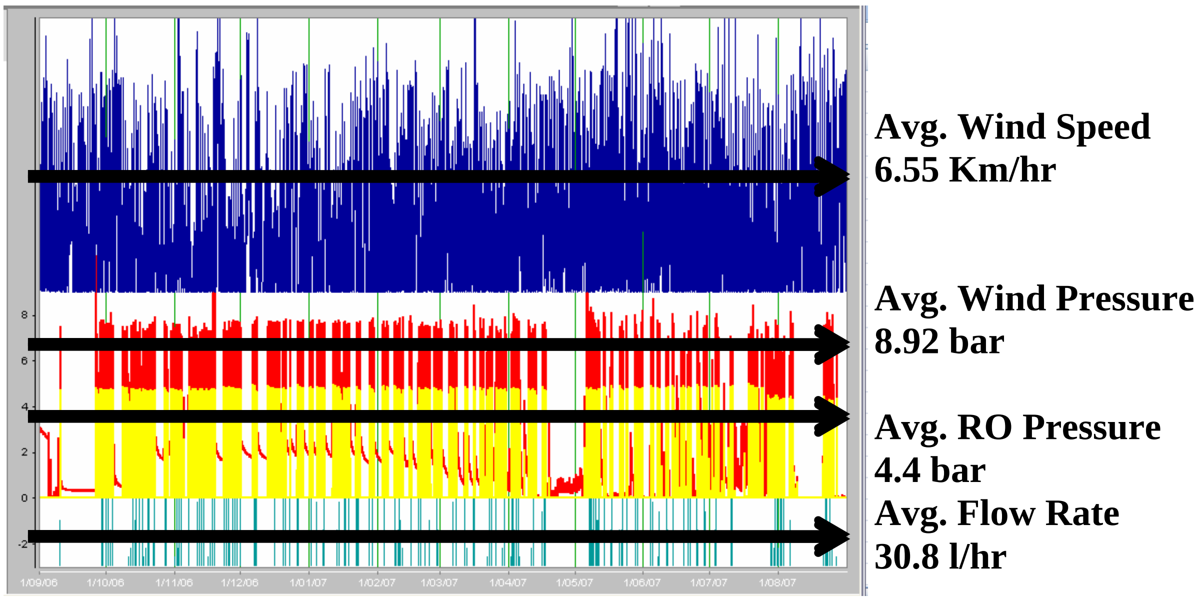

Figure No. 5 Average values of wind speed, wind pressure, RO pressure and flow rate during a 12 month eolic RO operating period.

Actual 2008 energy rate from the Mexican Electrical Energy Commission is \$ 0.24/KWh (USD), based on a 1.5 KWh/m^3 energy requirements for this type of filtration (TDS = 897 ppm), the savings related to energy cost were calculated at \$ 0.36/m^3 (USD). For a family of 5 with a 100 l/day of water consumption and a \$ 9.00 / day (USD) income, the savings represent \$ 13.0 USD per year.

Conclusions

The Eolic Energy Buffer System regulates inlet pressure at set point allowing commercial wind mills and reverse osmosis membranes to be connected and operate with regular maintenance. The Eolic Reverse Osmosis system represents a feasible, reliable and sustainable small scale desalination option for rural areas. Savings from the use of eolic energy in small reverse osmosis units can range from \$ 0.36 to 2.0 / m^3 depending on TDS concentration.

Reference

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