Human Powered Reverse Osmosis:
Producing Potable Water for Developing Nations

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Can reverse osmosis be driven by human power?
Could it be a feasible daily source of water for people lacking it?

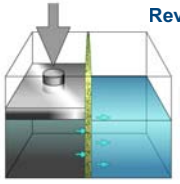
Introduction

"The Global Water Crisis"

- "Approx. one billion people do not have access to clean drinking water".[4]
- "3.575 million people die each year from water-related diseases".[4]
- "98% of water-related deaths occur in the developing world".[4]
- "Without food a person can live for weeks, but without water you can expect to live only a few days".[4]

Clearly, access to clean water is a highly overlooked, yet urgent issue for developing countries in which action must be taken immediately. In response to such a need, the idea proposed is to use a human driven bicycle to power a reverse osmosis system in order to produce clean drinking water for developing countries. This project is a proof of concept for a solution to be used as an immediate response, not a permanent or long term solution.

Reverse Osmosis



Reverse osmosis (or RO) is a process in which "water molecules are forced through a 0.0001 micron semi-permeable membrane by water pressure".[2] It is different from regular water filtration and is much more thorough. Although there is waste water involved, it is used to continually clean the membrane allowing it to last for several years.[2]

Design

Components

- Reverse Osmosis system with pre and post filters
- Hydrostatic hand test pump
- Waterline Components:
  - Washable sediment pre-filter
  - Pressure relief valve and pressure gauge
  - Water hammer arrestor
- Bicycle
- Modified Whitworth quick-return mechanism

Process of Purification

1. Place inlet hose in water source:
2. Pedal bike
3. Chains drive piston pump:
   The pedals turn the back sprocket by chain which in turn turns a sprocket on the mechanism by chain.
4. Mechanism operates pump:
   The mechanism is connected directly to the pump arm which pushes it up and down thus operating the pump.
5. Pump sucks water through first filter:
   Water travels through sediment filter before going to the pump which removes large granules and sediment to protect the pump.
6. Water is pushed through pump to filters:
   Water passes through all four filters and is cleaned thoroughly.
9. Brine water exits:
   Brine water was used to flush over RO membrane to continually clean it to increase life.
10. Clean water exits:

Results

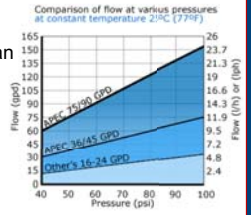
Numerical Analysis

A simple numerical analysis was performed to get an estimate concerning the work required (neglecting losses) to provide daily water needs:

$$P = Q*p$$

(where P is Power, Q is volumetric flow rate, and p is pressure)

- Maximum flow rate is desired for faster clean water production and is achieved with higher pressure as shown in the chart to the right.[2]



→ p = 100 psi

- Because the system has a 2:1 ratio of waste to clean water[2], 6.34 gph of clean water (from chart) and 12.68 gph of waste water is produced. The total flow rate is 19.02 gph.

→ Q = 19.02 gph

→ P = Q*p = 0.02 hp

- It requires 0.02 hp to produce 6.34 gph. This also means that it takes approximately 10 minutes of constant cycling to produce one gallon of clean water.

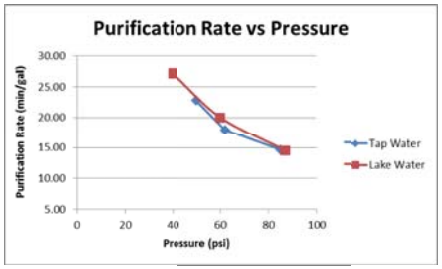
Testing

An experiment was performed using the built machine to achieve actual results for the analysis. Two tests were run using different sources of water and by varying the input pressure (performed below 100 psi to avoid damage to system) as the independent variable. Test data is shown below:

	Tap Water			Lake Water		
Test #	**1a**	**1b**	**1c**	**2a**	**2b**	**2c**
Pressure (psi)	50	62	85	40	60	87
Time (sec)	5.15	5.03	2.97	5.00	5.00	5.00
Amt Clean (gal)	0.23	0.28	0.20	0.18	0.25	0.34
Amt Brine (gal)	0.15	0.21	0.11	0.16	0.20	0.17
Ratio (clean/brine)	1.53	1.36	1.86	1.12	1.25	2.00
Rate (min/gal)	22.73	17.90	14.61	27.23	20.00	14.55

Discussion

The data was organized into the following graph to show how long it takes to produce a gallon of water:



A healthy human can provide 0.10 hp for a sustained 8 hours before exhaustion.[1] The device only needs approx. 0.02 hp. Pedaling only needs to be provided for 15 minutes per gallon. The World Health Organization states that, only ½ gallon of drinking water is needed per person per day.[3] Note: entire machine cost approx. $600.

Conclusion

From the analysis and tests performed on this project, it takes less than 8 minutes of easy pedaling to provide a person's daily water needs. It can thus be concluded that human powered Reverse Osmosis is not only feasible, but an efficient and effective method for providing clean drinking water to those in need.

References

1. "Human Powered Vehicles 1." Urieli, Israel. Ohio University, n.d. Web. 20 Mar 2011. <http://www.ohio.edu/mechanical/programming/hpv/hpv.html>.
2. "RO-CTOP Ultra Reverse Osmosis System." FreeDrinkingWater.com. APEC, 2010. Web. 20 Mar 2011. <http://www.freedrinkingwater.com/ro-counter-detail.htm>.
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4. "Water Crisis '09." Water.org. Water.org, Inc., 2009. Web. 24 Mar 2011. <http://static.water.org/pdfs/WaterCrisis09.pdf>.