National Aeronautics and Space Administration

Forward Osmosis Bag: Ground testing the Prospect of Using Alternative Water Sources for Drinking Water

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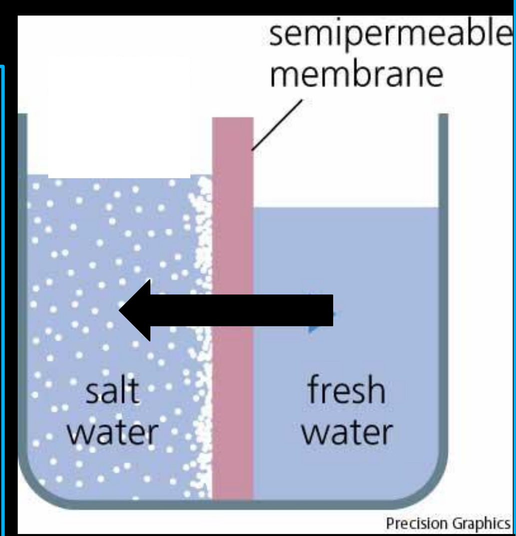
Abstract:

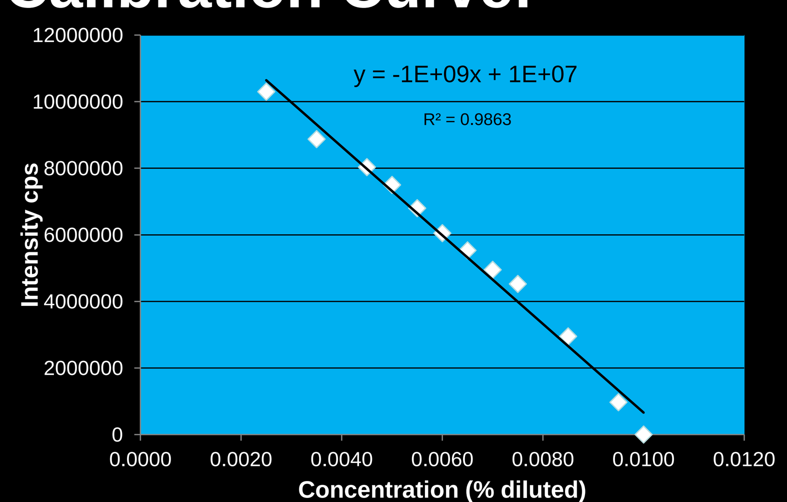
On the STS-135 Space Shuttle mission, launched July 8, 2011, a forward osmosis bag (FOB) study will be conducted. At NASA Ames this summer, the ground truth testing is being conducted for results comparisons. The FOB technology is derived from a commercial product, the X-Pack water filter. It is expected that the current system will retrieve 60% of the water from the grey water source. This concept could be used in space to provide drinking water in emergency situations.



Background:

Forward osmosis operates by utilizing an established concentration gradient across a semi-permeable membrane to move water molecules from one side of the membrane to the other. This concept is exploited to harvest drinking water from grey water sources such as urine, sea water, or vehicle water. In this experiment, potassium chloride (KCl) dissolved in water is used to simulate grey water. The KCl water is inserted into the FOB on one side of the membrane and highly concentrated sugar water is inserted on the other. The high concentration of sugar solutes creates a gradient that drives water molecules to pass through the membrane and enter the other side. The membrane properties prevent the solutes from diffusing, allowing only the water molecules to be harvested from the solution. The FOB efficiency is tested by use of a fluorescent dye marker in the sugar water side of the bag. The concentration of the dye decreases as more water diffuses across the membrane. The concentration of the dye is measured using a fluorometer and comparing intensity readings to intensity values of known concentrations.

Calibration Curve:



A calibration curve was required to compare collected data to intensity readings of known concentrations.

Two solutions are used in the forward osmosis bag.

Creating Solutions:

A FEED solution composed of sugar water and fluorescent dye is used to establish a strong concentration gradient and pull water from the other solution. This solution becomes more dilute as the experiment continues.

A DRAW solution composed of salt water and blue dye is used to simulate grey water and provide the source for water to be pulled from.

FEED Solution	Grams per 1.0 Liter	DRAW Solution	Grams per 1.0 Liter
Potassium Chloride (KCl)	15.00	Glucose	328.00
Methyl Blue	0.02	Fructose	361.00
DI Water	5000	Fluorescein	0.10
		DI Water	310.90

Photos to the right show the process of making the solutions

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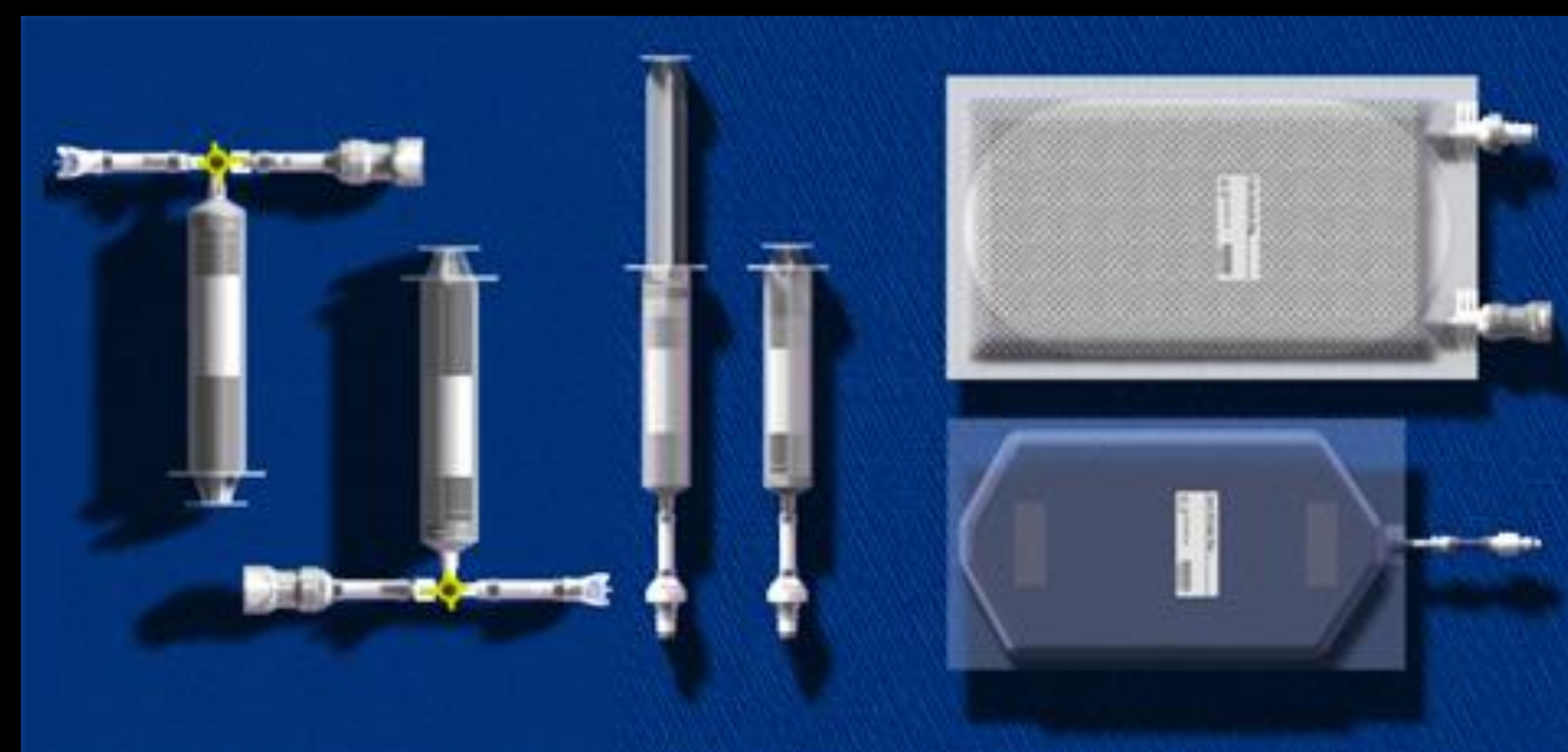
Performing Experiment

1. Insert FEED and DRAW liquid into either side of the membrane of the FOB using syringes
2. Lay bag flat on the counter and wait 5 hours before sampling
3. Take a 60 ml sample from the DRAW side and measure remaining liquid in both FEED and DRAW sides
4. Use a fluorometer to measure intensity of dye in the sample and relate to amount of water recovered using calibration curve



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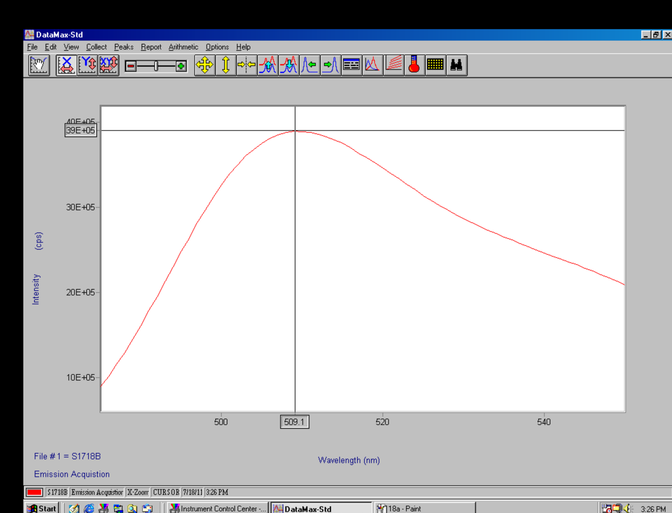
Data Analysis



The fluorometer is used to analyze the intensity of the fluorescein dye in the sample.

The fluorometer measures intensity in counts per second (cps).

The intensity reading is put into the equation of the line from the calibration curve as the variable "Y"

The equation is solved to find the "X" variable of the concentration

$$Y = (-1x10^9)X + (1x10^7)$$

The concentration is an indication of how diluted the solution has become. In other words, the concentration tells us how much water from the FEED side entered the DRAW solution side of the membrane.

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References:

Roberts, M. , M. Soler, T. Mortenson, H. Levine, M. Birmele, and L. McCoy. (2011) Flux Testing of the Forward Osmosis Bag (FOB), A Personal Water Purification Device for Microgravity Applications, 41st International Conference on Environmental Systems

Flynn, M., S. Gormly, and T. Richardson. (2010). Lightweight Contingency Water Recovery System Orion Water Landing Desalination Contingency Option, 40th International Conference on Environmental Systems, AIAA Publication # 2010-6126

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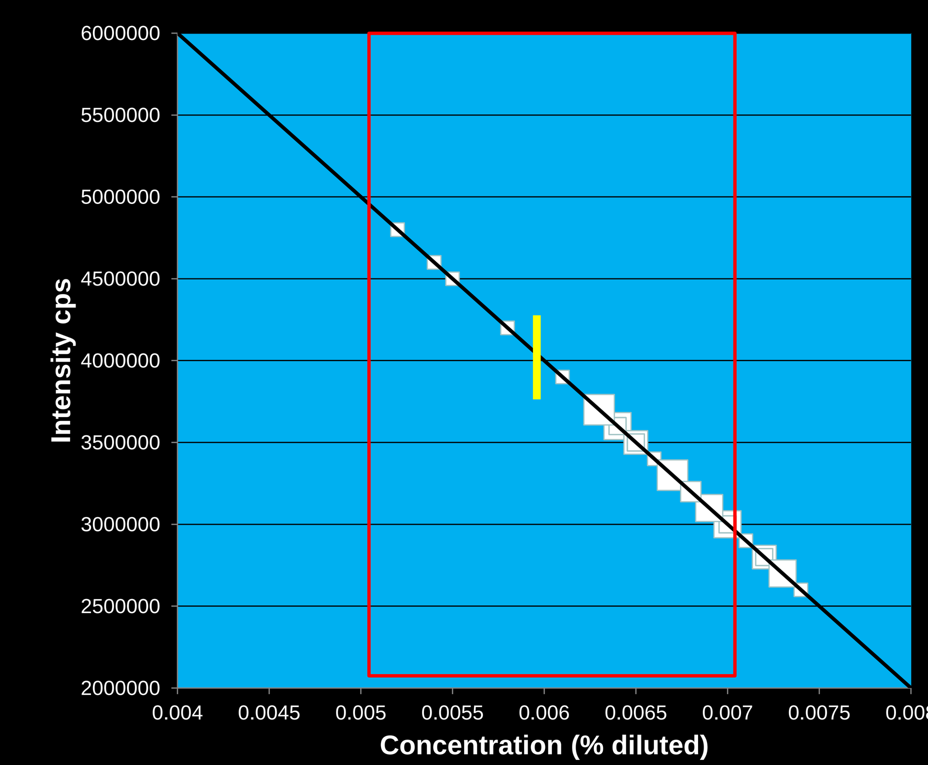
Graph

Yellow line shows expected efficiency

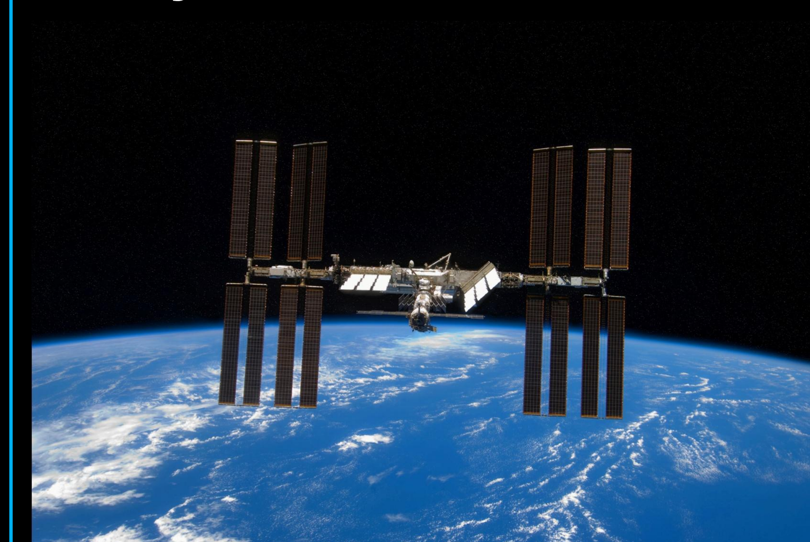
Red box indicates expected range for data points

Line indicates the calibration curve

Data points seem to fall near the expected value of 60% water recovery



Analysis



The photo above is of the International Space Station. This is where Atlantis was returning to earth from when the space experiment was conducted.

We ran several experiments with 2 bags at a time to practice and get an idea of what the data should look like before the 10 bag runs for large data collection.

During this time we discovered that the amount of air in the bag plays a significant role in the accuracy of the data collection. This information was relayed to other NASA scientists from Kennedy Space Center.

Conclusions

The data from volume measurements of recovered fluid suggests that the FOB is able to recover between 56% and 58% of the water. The data from the fluorescent dye measurements of recovered fluid suggest that the FOB is able to recover between 66% and 69% of the water.

Based on these experiments it seems that this may be a viable emergency water source. But, if this is to be used as a long term source of drinking water, a more efficient membrane may need to be tested.

Astronauts aboard Atlantis Space Shuttle conducted the same experiment on the last day of their mission before returning home to earth.