University of South Florida

Clean Drinking Water using Advanced Solar Energy Technologies

PI: Lee Stefanakos; **Co-PI's:** Yogi Goswami, Matthias Batzill, Maya Trotz, Sesha Srinivasan
Graduate Students: K. Dalrymple

Description: Availability of fresh water is one of the biggest problems facing the world and Florida is one of the most vulnerable states to fresh water shortages. Moreover, Florida ground water is contaminated in many locations from leaky underground tanks, agricultural pesticides, and other chemicals. Although possible to desalinate abundant sea water, conventional systems are too energy intensive. Solar energy can provide the needed energy, and innovative new solar vacuum (USF) and humidification/dehumidification (UF) desalination systems can provide adequate fresh water for the state's needs. Systems will be developed for both bulk water desalination and small community needs/disaster response. We will also develop photocatalytic disinfection systems to remove contaminants and integrate these technologies with solar PV for complete water supply systems
Budget: $220,664
Universities: USF

Project Summary

This project report is composed of two components: (A) solar desalination and (B) solar photocatalytic disinfection.

Solar Desalination: The objective of this project is to develop an economically–viable and an environmentally–friendly desalination system that requires less energy and uses renewable energy for its operation. The most common desalination technique, multi–stage flash, will be modified to have its system vacuum created passively and its thermal energy requirements provided by solar radiation. The proposed modifications are expected to further the feasibility and broaden the applicability of the desalination process. A thorough literature review was conducted to assess the work that has been reported on conventional and sustainable desalination systems to date. A preliminary theoretical analysis was conducted to help design a pilot unit. Experimental simulations were carried out using a lab-scale indoor pilot unit under varying conditions. A detailed computer model is being developed to simulate the proposed desalination method. The model is built based on the original theoretical model and the obtained experimental results.

Solar Photocatalytic Disinfection: The objective for this task is to develop an economically–viable and an environmentally–friendly desalination system by lowering its energy demand and employing renewable energy to drive its operation. The most common desalination technique, multi–stage flash, will be modified to have its system vacuum created passively and use solar energy. A thorough literature review was conducted to assess the work that has been reported on the modeling of photocatalytic disinfection systems to date. The rationale for this study is that the development of a mechanistic model for photocatalytic disinfection will allow scientists and engineers to develop design and analytical tools to optimize photocatalytic disinfection systems so that their efficiency. A series of experiments were set up to test the hypothesis that overall disinfection rate is dependent on the rate of lipid peroxidation. Important parameters, which have an effect on the peroxidation rate, were varied and the overall inactivation rate for *E. coli* was observed. The bench-scale experiments are still ongoing. To ensure that our model can translate to the design of real systems, a pilot-scale system was proposed. The design of the system has been complete. Two systems will be used. One such system is already in operation and the other system is under construction. Both systems are capable of being used under solar conditions in outdoor.

2010 Annual Report

Solar Desalination

Natural Vacuum Solar Flash Desalination:

Experimental and theoretical simulations of a n ovel sustainable desalination process are done using a pilot unit built to depict the proposed desalination system. The simulated process could use solar energy or other low grade heat source, vacuum is passively created and then maintained by the hydrostatic balance between the pressure inside the elevated flash chamber and the outdoor atmospheric pressure. Experimental and theoretical simulation results matched reasonably thus validating the developed model.

In addition, a comprehensive review of current desalination technologies including both commercial and pilot scale was carried out. Solar driven desalination processes were also reviewed. It showed that solar driven thermal flash/evaporation process achieved low cost and at remote small community solar driven desalination is convenient and reliable. A two-stage process was developed and modeled in computer. Further optimization is underway.

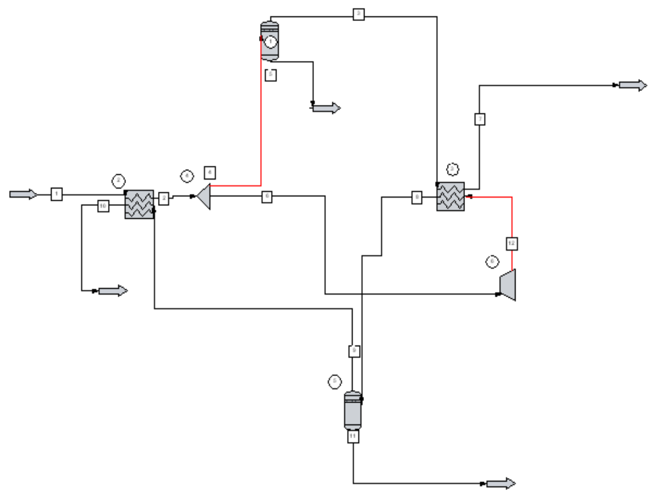

FIGURE 1. TWO STAGE DESALINATION PROCESS

Solar Photocatalytic Disinfection

Drinking water requires disinfection to remove pathogens (bacteria, viruses and protozoa). It is estimated that 1.2 billion episodes of waterborne infections occur worldwide every year. The US has a reputation for high drinking water standards, but severe outbreaks have occurred (*e.g. Milwaukee 1993 Cyptosporidium outbreak*). The number of food and waterborne disease outbreaks in Florida averages about 300/yr. Chlorine is the most common disinfection method, but forms potentially carcinogenic byproducts (e.g. trihalomethanes). Regulations limit the amount of disinfection byproducts in drinking water.Alternative disinfection methods are available, but many are energy intensive and require expensive chemicals and equipment.

Specific Problem Description

The construction of an effective photocatalytic disinfection system for water purification is currently limited by the lack of reliable models to aid in the design and testing of these systems. Simplified models have been proposed, but most are inadequate because they rely on traditional disinfection theories which are not applicable to photocatalysis. Therefore, the major goal of this research is to develop a model for photocatalytic disinfection based on fundamental processes which may then be used to design water treatment systems in the state of Florida.

The following summarizes the progress since the last report:

Model Development

- A model was developed for photocatalytic disinfection and programmed into computer codes using the MatLab software
- The model is being validated with experimental data
- A series of other models have been tested with the experimental data derived in the research

Bench-scale Experiments

- The laboratory experiments with E. coli bacteria have been mostly completed. After careful data analysis, the decision was taken to explore lower concentrations of catalyst for more effective disinfection. The following experiments were completed:
  - Varying concentrations (0.0, 0.10, 0.25 and 0.5 g/L of P25 TiO_2); lower concentrations to be tested include 0.01 and 0.05 g/L.
  - Varying light intensity
  - Three (3) specific modifications to E. coli to influence resistance to disinfection

A. Publications & Conferences

1. A scientific review paper was published in the Journal of Applied Catalyst B: Environmental 98, (2010) 27–38.

2. Chennan Li, Mohammad Abutayeh, Yogi Goswami, Stefanakos Lee, Solar Driven Sea Water Desalination, 2010 FSAWWA conference.

3. The following manuscripts have been prepared and will be submitted during this reporting period:
   a. Lipid vesicles as model membranes in photocatalytic disinfection studies
   b. Application of the Fermi function and Weibull distribution to photocatalytic disinfection
   c. The influence of cellular fatty acids on *E. coli* resistance to photocatalytic disinfection
   d. Water Desalination Process with Solar Technology: A Review

4. The following posters and/or oral presentations were made at conferences:
   a. A probabilistic approach to photocatalytic disinfection modeling (USF College of Engineering Research Day, Tampa, FL)
   b. Lipid vesicles as model membranes in photocatalytic disinfection studies, (FESC Annual Conference, UCF, Orlando, FL)
   c. A model for the photocatalytic oxidation of cell membranes during water disinfection (AIChE Spring Conference, Austin, TX)