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Advanced Life Support - NASA Specialized  
Center of Research and Training (ALS-NSCORT)

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July 2004

## July 2004 Report of Progress

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## July 2004 Report of Progress

- 1 **Jim Alleman**  
**Solid-Phase Thermophilic Aerobic Reactor (STAR) Processing of Fecal, Food, and Plant Residues**
  - **STAR Reactor Operation**

STAR continued to operate at 6% solids with an 18-day retention time during the past month, allowing further collection of data. We are currently planning the next run and developing a testing matrix for further evaluation of the STAR system.
  - **Inedible Plant Biomass**

Hydroponically-grown inedible biomass has been collected and packaged for storage. Further material will continue to be collected. We are beginning small-scale testing of individual plant species and their response to treatment, and plan to begin adding plant biomass to the STAR reactor in early fall.
  - **Off-gas Scrubber and Analytical Work**

Evaluation and trouble-shooting for the off-gas scrubber has begun. Within the next few weeks off-gas analysis will begin, which will allow us to begin a mass-balance study. VFA, ammonia, pH, ORP, TS, and VS analysis continued this month.
  
- 2 **Charles Glass**  
**Nitrogen Cycling in ALS**
  - **Column Assessment of STAR Condensate**

With the conclusion of batch experiments the evaluation of the performance of our three best zeolites with both synthetic and actual condensate water from the STAR system continues. Over the past month we have treated approximately 5, 1L shipments of STAR effluent and we have another 5 L that we have received and stored at room temperature. The capability of the Chabazite: ZS500RW/H is still out performing the Clinoptilolite: ZS403TM and (Clinoptilolite: ZS403H). However, all of our selected zeolites perform better with synthetic feed with a higher ammonium concentration than the condensate water from the STAR system. We believe this is due to organic carbon and possibly other cations that are present in the condensate water and are taking steps to confirm this fact.
  - **Conclusion Pretreatment of Zeolite with Heat, KCl, NaOH, and HCl**

Experiments that were performed with Heat for 1, 2, or 3 hours, with soaking in KCl overnight showed no improvement in capacity for our top three zeolites. In addition, pretreatment with strong acid or base did not show any improvement in performance in batch tests. Consistently, however, equilibrium was reached in a shorter amount of time with the pretreatment processes and adsorption seemed to be more stable (less fluctuation in the sorbed concentration of ammonium). The advantages of  $K^+$  as the exchange cation may outweigh the loss of performance in the capability of the zeolites, but we are not comparing pursuing this line of questioning at this time.

3 Jeff Volenec

### **Solids Separation Water Removal from STAR Biosolids Effluent Using Plants**

- **Solid-Phase Aerobic Reactor (STAR) Biosolids Dewatering**

Plant tissue analyses from STAR biosolids dewatering experiment have been completed. The objectives of this experiment were to identify the biomass specie best suited for dewatering and capturing nutrients in STAR waste effluent and determine the mineral composition of biomass from the species used in dewatering and nutrient removal of STAR waste effluent. For all three treatments (Hoagland's nutrient solution, STAR, water), Hoagland's nutrient solution generally increased tissue concentrations for most elements tested. Tissue sodium concentrations of plants grown with STAR effluent were four times that observed with the other treatments.

- **Plant Growth Substrate**

Experiment is currently underway to test suitability of illite-montmorillinite-silica blend (Turface) as a growing substrate for STAR biosolids dewatering. Plants have been established in the Turface, including several wetland species shown to be tolerant of effluent loading near sewage treatment plants. STAR effluent applications are scheduled to begin in the next few weeks as effluent becomes available from cooperators in CIVL.

4 Jim Alleman

### **Liquid Freeze-Thaw (LiFT) Urine & RO Brine Processing for Advanced Water Recovery and Salt Separation**

- **Freeze Concentration Technique**

Collaborations with a freeze concentration company have resulted in a planned pilot plant study of water extraction recovery rates and cleaning capabilities of a model urine solution. The study will consist of two phases. Phase I involves off-site testing located at the company's pilot plant. Upon completion and process verification, Phase II will include on-site testing of urine samples at Purdue using the company's freeze concentration unit. Phase I studies should begin in September; if positive results are obtained, Phase II will follow after transportation and operation requirements are completed.

- **Bench Scale Freeze Concentration Studies**

Small scale versions of freeze concentration are still being conducted. Currently, approximately 30% water recovery rates are attained which include a clean water product. The small scale tests are a simple attempt to insure the ability of freeze concentration for water extraction from urine. Results are positive therefore Phases I and II, as described above, will be pursued.

5 Kim Jones

### **Membrane Processes in ALS**

- **Quantifying biofouling in MF/UF system**

Undergraduate fellow traveled to Purdue University to learn technique for quantifying bacteria growth on membrane surfaces. Static (no flow) experiments will be used as a screening technique for determining biofouling potential. BREATHe effluent will be used in these experiments to determine fouling of the following membranes: UF (PVDF, PS, CA, PES) and MF (PVDF, PES, PC).

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Concurrent flow-through experiments are being conducted with the Sepa crossflow system to determine flux/pressure profile and resistance of the fouled membrane layer for each membrane listed above.

- **Summer Fellowship Program (HU)**

Asha-Dee Celestine completed her summer fellowship working on membrane biofouling, traveling to Purdue University to learn new techniques and participate in 2<sup>nd</sup> annual Symposium.

- **Ongoing tasks:**

MF and RO systems were completed, allowing permeate from MF unit to be used as feed for RO unit.

System was run to repair leaks and ensure data acquisition techniques

- **Upcoming tasks:**

Evaluate membrane modification techniques

Operate system with integrated disinfection

Evaluate cleaning techniques

### 6 Kathy Banks

#### Treatment of Grey Water Using Gas Biofilters

- **Development of methods for use of an internal standard for surfactant analysis on the LC-MS**

Issues of instability of operation of our LC-MS instrument have been encountered. For purposes of QA/QC, a method has been developed to run internal standards during the LC-MS sample runs. A total of 12 chemicals were examined for potential use as an internal standard for analysis of Sodium Laureth Sulfate (SLES) and Disodium cocoamphodiacetate (DSCADA). Preliminary work showed that atrazine could potentially be used, however the peak eluted too close to the DSCADA peak causing interference. Finally, several atrazine like compounds were examined and propazine has been determined to be a likely candidate for use as an internal standard. The propazine peak elutes in the middle of the SLES and DSCADA peaks.

- **Preliminary investigation of surfactant characteristics for application for liquid/gas equilibrium experiments**

Fundamental characteristics of surfactants were investigated. SLES and DSCADA, the surfactants present in Pert Plus for Kids, showed relatively high foaming effects and solubility. On the contrary, polyalcohol ethoxylate and alkoxyated isopropanolamide showed extremely low foaming and formed emulsion in water. Understanding of the different characteristics of the surfactants will provide guidance for understanding of the effect of foam to the phenomena of phase transfer of gases in BREATHe system.

- **Steady State Operation of Six BREATHe reactors**

Six replicate BREATHe reactors were operated at steady state conditions through the month of July. Several design problems were encountered with regard to gas entering the liquid lines and vice versa. These design problems have all been overcome and we are ready to begin to introduce gas contaminants to the systems. Additionally, the reactors will be challenged by adding a urine wastestream to the graywater wastestream. Effects to surfactant biodegradation will be studied.

- **Integrated work with membrane group at Howard**

Some time was spent this month training Asha-dee Celestin from Howard University biological methods that will be applied to the membrane studies. Biofouling of membranes will be studied using effluent from the BREATHe reactors. During Asha-Dee's time at Purdue, she was taught methods to study biological attachment to membranes including removal of the bacteria from the membrane and subsequent plate counting.

## 7 Al Heber

### Gas-Phase Revitalization Using Biofilters in ALS

- **Biofilter setup**

Connected biofilters to gas sampling system and built spray headers and nutrient addition system.

- **ALS IAQ modeling**

Based on the 3-story ALS cabin used project phase III with one level about 3.5 m x 3.5 m x 3 m, the following was done in the program:

Simulated network airflow and convective contaminant mass transfer within cabin

Simulated exposure assessment and weekly job scheduling of crews.

Set up and simulated air ducts and pipes.

- **Biofiltration modeling**

Constructed chemical equilibrium (stoichiometric) equations for seven input chemicals to predict ultimate microbial consumption of nutrients and oxygen and

microbial generation of carbon dioxide and water.

Found half degradation constants for some input chemicals from literature.

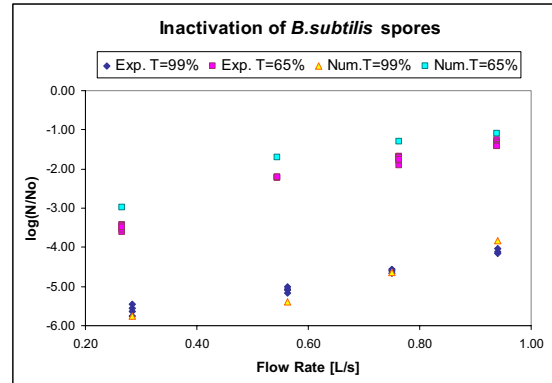
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### 8 Chip Blatchley

#### Potable Water Disinfection Subject to Extended Space Travel Constraints

- **Computational Simulation of Continuous Flow Experiments**

Numerical simulations of flow-through experiments were completed for all flow rates. The Figure on the right represents a comparison of experimental and numerical predictions for the inactivation of *Bacillus subtilis* spores at different flow rates and water transmittance values. The experimental and numerical results are in good agreement and improvements of the numerical method will be made for an even better fit with the experimental results. This is a validation that the numerical method can be used for designing an efficient UV disinfection system for extended space travel.



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- **Conference Presentations**

Two papers were presented at the ICES conference in Colorado Springs:

1. Paper number 2004-01-2516 Complementary disinfection for long-term space missions: Preliminary system design
2. Paper number 2004-01-2538 Process performance of ultraviolet disinfection systems for long-term space missions

### 9 Bruce Applegate Mike Ladisch

#### Bioamplification Using Phage Display for the Multiplexed Detection of Pathogens in Potable Water and Food

- **Work continued using the previously constructed recombination system for the modification of the *E. coli* O157:H7 bacteriophage *phi* V10.**

We are performing the recombination and lysogen rescue experiments with mixed results. (Note: We are still investigating the anomaly in the sequencing data that suggests a unique DNA packaging requirement for *phi* V10.)

- **Work was continued on the insertion of a unique binding epitope in the tailspike protein of the *Salmonella* spp. bacteriophage P22.**

Initial work was begun on inserting the modified tailspike gene in the previously constructed P22 recombination vector.

- **A *Listeria* bacteriophage was isolated.**

Preciaus Heard (Summer Fellowship Student) was successful in isolating a *Listeria monocytogenes* bacteriophage. We are currently evaluating the isolated bacteriophage for specificity and its genome characteristics.

A poster presentation was presented at the ASM Conference on the New Phage Biology Aug. 1-5, 2004, Key Biscayne, FL entitled: "Bioamplification using phage display for the detection of pathogens." M. Shroyer (NSCORT Grad student), U. Minocha\* (NSCORT Grad student), M. Ladisch, B. Applegate; Purdue, West Lafayette, IN.

\* currently in Kosovo as his National Guard unit was activated.

**10 Paul Brown**

**Waste Treatment Using Tilapia**

- A formal feeding trial was completed in which thermophilic bacteria, wheat waste products from food preparation, soybean stubble, cowpea waste, sweet potato residue and inedible components from basil were fed to tilapia
- All products were accepted by fish
- Fish grew best when fed wheat products and dried bacterial residue.
- Fish carcasses are being analyzed to develop a mass balance for the respective feeds
- A thorough nutritional analysis is also being conducted on whole fish, fillets and wastes

**11 Cary Mitchell**

**Minimizing ESM for ALS Crop Production**

- LED Lighting system completed and long-duration hardware-performance testing initiated at Orbitec.
- "Build a hydroponics system" outreach activity completed and test system constructed for NSCORT Outreach Program. Suggested experiments list compiled.
- Hydroponics pH control system testing and fine tuning continued.
- Strawberry cultivar and cultivation tests continued. Plants for growth chamber temperature study readied.
- Sweetpotato training/basal defoliation experiments continuing.
- Water sampling from hydroponics system finished for bacteriostatic studies. Hydroponics systems containing cowpea, basil, and triton peppers harvested and fresh material weighed. Fresh crop waste biomass sent to STAR group.
- Apogee and Perigee wheat planted for use in Lisa Mauer's Food Technology lab.

**12 Caula Beyl**

**Solid Waste Processing Using Edible Fungi**

- **Enhancing growth and fruiting of edible fungi on wheat straw using urea**

Two strains each of the edible fungal species *Lentinula edodes* (LE001, LE002) and *Pleurotus ostreatus* (Grey dover, Blue dolphin) were grown in fine wheat straw amended with urea at 0.0, 0.001, 0.01, 0.05 and 0.1M as N source. The objective of the study was to determine optimal concentrations of N for growth and fruiting, and to compare the relative growth and fruiting of the fungal species on the enriched wheat straw. Major differences were observed between the



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strains in growth and colonization of the substrates and fruiting. *P. ostreatus* (Grey dover) was most responsive both in mycelial growth and fruiting, whilst urea at 0.001M was most favorable to mycelial colonization. Other parameters being evaluated include changes in pH and C/N ratio over time.

- **Evaluation of STAR residue-amended rice straw for growth and fruiting of strains of oyster**

Previously, we reported that *Pleurotus ostreatus* mycelia grew well in STAR residue-amended rice straw tolerating up to 60% concentrations of the residue with subsequent basidiocarp production. Our current goal is to increase the residue concentration in the mixture to 100% and evaluate growth and fruiting of different strains. Choice of strain is critical for tolerance to higher concentrations of residue. The ability to degrade higher concentrations of STAR residue will ensure a more rapid way to recycle this biosolid waste in the ALS system. Three strains of *P. ostreatus* (Pohu, Grey dover and Blue dolphin) were seeded in rice straw amended with STAR concentrations 0, 20, 40, 60, 80 and 100%. Mycelial growth and basidiocarp production are being evaluated.

- **Preparation and submission of research abstract for the 2004 NSCORT Summer symposium**

Two abstracts of research to be presented at the 2004 summer research symposium entitled "Growth response of edible fungi on processed crop biomass and sludge amended rice straw" and "Growth of shiitake and oyster mushrooms on processed wheat straw modified with varying concentrations of urea" were prepared and submitted.

13 Lisa Mauer

### Novel Storage and Packaging Operations

- **Attended ICES meeting in Colorado Springs and presented 2 papers (as previously noted). Both papers were selected for publication in SAE Transactions**
- **Planted Apogee and Perigee wheat in greenhouses for replication of wheat protein quality studies**
- **Located radiation source for low dose gamma ray studies, will receive radiation training in August**

- **Developed laboratory activities to be used for the August 5 Key Learning Camp**

Activities will include: 1) Discussion of the space food system and why foods for space will be different than many common "Earth" foods. 2) What is vacuum packaging and why do we use it? All students will vacuum package foods to take with them. 3) What is freeze drying and why is it used for space foods? All students will view the freeze drying process in the pilot plant and sample a variety of freeze dried foods (ice cream, carrots, bananas). 4) What happens to foods in a vacuum? Students will examine effects of vacuum on a variety of foods. 5) Why do astronauts eat tortillas? Students will make tortillas from scratch and discuss dehydration, heat transfer, and frying.

**14 Leonard Williams Optimal Food Safety in ALS**

- **Determination of critical points**

AAMU Graduate Student has completed preliminary work on determination of critical points in pre-harvest salad crop production.

- **Determination of Biofilms on Salad Crops**

Graduate student continue work on biofilm formation on salad crops and microenvironments or 'niches' created by spoilage and pathogenic bacteria.

**15 J. Pekny, G. Chiu, Y. Yih Systems Modeling of ALS**

- **Continuing work on Diet Optimization**

The purpose of this work is to find the best diet cycle that minimizes the ESM of the overall ALSS. Given the activity schedule of the crew members, the model will be able to calculate the necessary nutritional requirements of the crew members. A diet cycle (20-30 days cycle) will be constructed that meets these requirements while minimizing the ESM. This model will also be able to give the necessary biomass amount required to construct this diet. Selen Aydogan contacted Dr. Jean Hunter to receive the recipes that are developed for ALSS diet and these recipes will be the starting point of the optimization module.

- **Continuing work on Plant Scheduling module**

Given the demands for the ALSS crops, this module is able to determine the planting schedule that will optimize the system behavior for a given period of time. The formulation of this module is completed and currently we are implementing the formulation.

- **Presentation in ICES 2004**

Selen Aydogan presented the paper "A Prototype Simulation Based Optimization Approach to Model and Design an Advanced Life Support System (Selen Aydogan, Seza Orcun, Gary Blau, Joseph F. Pekny, Gintaras Reklaitis)" in International Conference on Environmental Systems, 2004.

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### 16 John Trimble

#### A System Dynamics Approach to Modeling the Advance Life Support System

- Charita Brent presented a poster at the International Multi-conference in Computer Science and Computer Engineering - International Conference on Modeling, Simulation and Visualization Methods (MSV2004) titled ***“Applying Knowledge Elicitation Techniques to Construct Membrane Flight Simulator,” Las Vegas , Nevada . June 2004.*** This was a culmination of the modeling effort she did while working on her MS in computer science at Howard University. She is currently refining this work to present a paper at the National Technical Association’s National Conference in September.
- John Trimble developed a prototype high-level ‘qualitative’ system dynamics model based on the “bioregenerative life-support system (modified from Hoff et al. 1982)” that is presented in the Introduction of our research plan description. This model is built using Stella. It will be used to illustrate the general causal relationships between components of the ALS system and develop a better understanding of the precise quantitative relationships in play as our complex system evolves. The next step in the revising of this prototype is to quantitative features and examine different scenarios.
- John Trimble has modified the Systems and Computer Science senior level Systems Management Course to include components that utilize the system dynamics models build for the NSCORT project. The course will use both the ‘Water subsystem’ models developed by Dr. Trimble and extended by Charita Brent over the past year and the recently developed ‘prototype high-level’ model. This course is a required course of all systems and computer science majors at Howard University and presents an opportunity to involve a wider range of students in our project and also identify potential graduate students with an interest in the systems component of ALS.

### 17 Julia Hains-Allen

#### Outreach

- **Mission To Mars Professional Development**

Julia Hains-Allen in collaboration with IVY Tech Community College offered a 2-day professional development for area middle school teachers. This professional development offered hands-on experience with the 10 modules in Mission To Mars along with background content information and classroom curriculum integration.

Informal educators from an area science museum, Imagination Station, were among the group of educators trained. Imagination Station will offer Mission To Mars as an after-school program in the fall. The program will be offered each month for seven months, involving a different Lafayette School Corporation elementary school each month.

- **Mission To Mars Library Program**

Sixty children participated in a Mission To Mars Library program involving the Mission To Mars learning modules Ghost Shrimp Ecosystem and Growing Plants in Space. The learning modules were presented by Dan Egel, Purdue Extension Plant Pathologist in Knox County, IN.

- **NASA's Biological and Physical Research Enterprise and the Vision for Space Exploration Teacher Workshop**

Thirty teachers in the Colorado Springs area received an introduction to the Mission To Mars module, a complete Mission handbook along with supplemental materials for classroom integration as part of a 5 day professional development workshop July 19-23, 2004. Gary Coulter presented the module.

18 Dave Kotterman

**ALS NSCORT Center Activities**

- **Center Personnel Attended ICES July 19-22, 2004**

Ten members of our Center attended ICES this year with eight papers presented.

- **Kiwanis Presentation**

On July 27<sup>th</sup>, Dave Kotterman presented "Artificial Closed Eco-Systems for Human Habitation of Space" to 50 business leaders in Kiwana, Indiana.

- **Annual Report 2004**

Began compiling information for use in the ALS NSCORT annual report.