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

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February 2005

## February 2005 Report of Progress

James E. Alleman

Charles Glass

Jeff Volenec

Kimberly L. Jones

M. Katherine Banks

*See next page for additional authors*

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## Authors

James E. Alleman, Charles Glass, Jeff Volenec, Kimberly L. Jones, M. Katherine Banks, Albert J. Heber, Ernest R. Blatchley, Bruce Applegate, Mike Ladisch, Paul B. Brown, Cary A. Mitchell, Caula A. Beyl, Lisa J. Mauer, Leonard Williams, Joseph F. Pekny, George Chui, Yuehwern Yih, and Julia Haines-Allen

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### 1 Jim Alleman

#### Solid-Phase Thermophilic Aerobic Reactor (STAR) Processing of Fecal, Food, and Plant Residues

- Final reconstruction of our next-generation STAR reactor was completed in early November 2004, and the reactor was placed shortly thereafter back into operation.
- Commensurate with this restart, we raised our influent solids loading level to 9% total solids, as compared to prior runs at 6% or lower.
- Unfortunately, what we subsequently learned was that our reactor could not handle this high solids loading, or at least could not handle this high loading based on the employed startup procedures. In effect, the biomass in the reactor lost full metabolic capability, such that the reactor had to be shut down in late December.
- The reactor was then cleaned out and is now being restarted at the prior 6% solids concentration.

### 2 Charles Glass

#### Nitrogen Cycling in ALS

- **Zeolite Assessment**

Experiments with Zeolites were completed in November 2004. The masters student on the project has successfully completed her thesis and defended the work. Zeolites clinoptilolite and chabazite effectively adsorbed ammonia both at low and high concentration 100 – 1000 mg NH<sub>3</sub>-N/L. The Langmuir isotherm gave an adequate correlation coefficient compared to the Freundlich isotherm correlation coefficient. The zeolites in this study have the potential to be excellent ion exchangers under peak ammonia concentrations with signature steep breakthrough curves. Of the tested zeolites used in this study, the chabazite ZS500RW/H statistically proved to be the best at adsorbing ammonia under the present conditions. Finally, pretreatment techniques, conducted to improve adsorption capacity, proved to be successful. The most effectual pretreatment process was the one hour heat pretreatment at 600°C. We feel confident that we understand the capabilities of the zeolites selected to adsorb ammonia.

- **Preparation for Year 3**

As a part of the original proposal and first year of operation, one of the goals of this project was to evaluate the nitrification then denitrification of the condensate water scrubbed from the gas of the STAR system. The original hypothesis was that it was possible to regenerate a zeolite through nitrification of the ammonia adsorbed to the surface. After issues with nitrification in columns during year one occurred, predominantly acclimation and the alkalinity requirements causing a higher ESM than adsorption, in the second year an evaluation of zeolites to remove ammonium from solution was performed and successfully completed.

This year the PI will investigate the oxidation of ammonium through nitrification in a batch reactor treating the proposed flow rate of the condensate production from the STAR reactor (0.6 L/day) at a concentration up to 1000 mg/L NH<sub>4</sub><sup>+</sup>-N. The goals of the project will be to:

1. Establish a culture on a synthetic wastewater, acclimating the biomass to an influent concentration of 1000 mg/L
2. Feed the culture the condensate from the STAR reactor when the shipments are received from Purdue
3. Add chabazite and clinoptilolite to the acclimated biomass to determine if this

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enhances the capability of the mixed culture to oxidize ammonium to nitrate

4. Determine the ability to perform nitrification then denitrification in the same system, completing the nitrogen cycle

**3 Jeff Volenec**

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

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

STAR effluent dewatering/nutrient recycling experiments will commence pending steady-state operation of STAR and production of effluent/solids.

**4 Jim Alleman**

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

- The development of a 2nd generation freeze concentration process including crystallizing tank and ripening tank have been completed. Development work on effective wash column is on-going.
- The theoretical modeling portion of the research is now underway. Thermodynamic properties of the different components in the ersatz urine solution are soon to be determined. In addition, the company we are collaborating with will soon be using their software to develop the model based on the mentioned component properties.

**5 Kim Jones**

### **Membrane Processes in ALS**

- **Microfiltration Membrane System.** Focus of year 3 will be on modifying commercially available MF membranes to reduce fouling. Two different grafting techniques will be evaluated for fouling reduction and flux. When considering mode of modification, ease of replacement and stability in zero-gravity environments will also be considered.
- Biofouling studies are also being analyzed by type of bacterial suspension by relating microbial attachment as a function of number of cells in suspension. On going studies have been studying biofouling as a function of membrane surface roughness (via AFM), pore size and hydrophobicity.
- **Reverse Osmosis/Nanofiltration Membrane System.** System is being retrofit to allow for more stable operation. Unstable pressure differences have hindered steady state operation of the RO system. Concurrent modeling studies are being developed to determine the rate of replacement of the RO membranes as a function of rate of fouling (as quantified by buildup of irreversible fouling layer). Surfactant monomers and trace organics are surrogate foulants for this system.

**6 Kathy Banks**

### **Treatment of Grey Water Using Gas Biofilters**

- A set of six biotrickling filters are currently being operated. Three contain B-2000 packing material and 3 contain Biobale packing material. The operational performance of these trickling filters is being compared to six reactors containing Tri-pak packing material operated during the months of June through August, 2004. The highest TOC removal rates were observed in the reactors containing Tri-pak, 60% removal of TOC on average. Surfactant removal has been on average 96% in all reactors. A complete characterization of the effluent is currently underway so that the discrepancy between TOC and surfactant removal can be understood. It has been

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determined that there is no correlation between surfactant and TOC effluent concentration. The following tests are being performed weekly in addition to tests previously mentioned BOD<sub>5</sub>, COD, microbial counts, TSS, VSS, and TDS. An LC-MS is being used to look for peaks that may be representative of surfactant degradation by-products.

- The effects of the recirculation ratio on performance of biotrickling filters used to treat graywater is under investigation. The recirculation ratio was increased 5 days ago. The increase has resulted in some sloughing of bacteria from packing material. Changes in operational performance related to surfactant and TOC removal rates are currently under investigation.
- The mass transfer of ammonia gas into a liquid phase was investigated in water and surfactant solutions. The effect of the gas:liquid ratio was estimated to confirm the efficiency of ammonia solubility in surfactant solutions. In this experiment, milli-Q water, 500 ppm of SLES solution and 500 ppm of DSCADA were added to a 45ml vial. Ammonia gas concentration was 300ppm. Air-water ratios of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5 (solution volume/ air volume) were applied. After equilibrium, the ammonia concentration in liquid was measured using Ion Selective Electrode (ISE) Method. For each solution, the highest concentration of ammonia in liquid was observed at air-water ratio of 0.25 and ammonia concentration was decreased as the portion of gas phase was increased, but removal efficiency was different for each solution. Below a gas to liquid ratio of 3.5, water without surfactant was most efficient for removing ammonia from the gas phase. However, when the liquid:gas ratio was increased above 3.5, solutions containing surfactant sorbed more ammonia than clean water. Further studies will address the causes for this phenomenon. In particular the effects of pH, surfactant characteristics, and effects of foam will be addressed.

### 7 AI Heber

#### Gas-Phase Revitalization Using Biofilters in ALS

- In the past month, steady progress has been made with experimental setup of the biofilter tests described as follows: 1) We have achieved our desired biofilter inlet air stream humidity by using the Parker needle valve to control steam injection from the steam generator. We are able to bring the inlet air stream to an increased humidity level that simulates the cabin air conditions, while at the same time such increased humidity level is also essential for maintaining proper moisture content of the biofilter bed for successful biofilter operation. The Swagelok needle valve is currently being tested to see whether it provides us with a more precise control of steam injection; 2) We are now operating the KinTek 585A and KinTek 570C permeation oven at different oven temperatures to achieve the permeation rates that correspond to our target biofilter inlet n-butanol and acetone concentrations; and 3) Quantification of the spectrums is underway for FTIR calibration. Upon completion of these tasks within a couple of weeks, we are ready to test massively the decontamination capacity of the bioreactors operated at different operating strategies.
- The effects of gravity on two-phase flow in biotrickling filter were studied by incorporating several mathematical equations in the biotrickling filter model. Model simulations were run to study the effect of gravity on minimum flow rate for water flooding, water film thickness, and liquid-phase mass transfer coefficients.

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- Met with the center director, Dr. Cary Mitchell for his latest input on reduction of ESM using bioregenerative techniques for ALS air revitalization. At his suggestion, we are considering having plants as our compost biofilter medium supply to test its air cleaning capabilities in comparison with other packing medium.
- Two ICSE papers, one on the biofilter experimental setup and the other on the biofiltration modeling, are being developed for submission in early March.

### 8 Chip Blatchley

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

- **Ion Exchange and Ascorbic Acid for Iodine Removal**  
Experimental results suggest that ion exchange and ascorbic acid are effective at removing iodine residuals from water. Ascorbic acid reduces residual (oxidized) iodine species to iodide. Iodide is then adsorbed onto ion exchange resin. Ascorbic acid does not appear to compete with iodide for ion exchange sites.
- ***B. subtilis* Experiments**  
Laboratory equipment was recently purchased for the growth of *B. subtilis* (spores) for dose-response experiments. Experiments with the spores are expected to begin in late February.
- **Investigation of an alternative UV intensity field**  
An alternative UV intensity field model was incorporated into the numerical model that is to be used for evaluating different designs of UV reactor systems for extended space travel. This new model, called the Spherical Source (SS) model, represents a potentially important improvement in the accuracy of representing the intensity field emanating from a UV lamp as compared to the previously used Line Source Integration model. The microbial inactivation results simulated incorporating the new SS model will be compared to inactivation results obtained previously obtained with the LSI model and experimentally measured inactivation.

### 9 Bruce Applegate Mike Ladisch

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

- **Evaluating Bacteriophage Infectivity in a Food Model**

To optimize the assay for minimal food sample preparation, we utilized a previously developed 2 component system of T4 phage bioluminescent *E. coli* (lux) host strain to evaluate the effect of variables such as food components or laboratory media on phage infection. *E. coli* lux cells were serially ten-fold diluted with sterile peptone water, LB broth, and LB mixed with 10% (w/v) ground beef. Samples were analyzed by addition of serial dilutions of T4 phage and reduction of bioluminescence was monitored over time using a Wallac Microbeta scintillation counter. Results showed decreasing bioluminescence for *E. coli* ( $10^7$ - $10^5$ ) cfu/ml in the presence of increasing T4 phage concentrations over time. At approx.  $10^7$  cfu/ml of *E. coli* lux, a dynamic range of T4 phage concentration was  $10^9$ - $10^6$  pfu/ml with a detection limit of approx.  $10^5$  pfu/ml in both LB and LB with ground beef with peptone not exhibiting any decrease in luminescence. However, the rate of decrease in bioluminescence was greater in LB than that in LB with ground beef. This study suggests that incorporating LB into the ground beef for sample preparation facilitates phage infection and replication.

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10 Paul Brown

### Waste Treatment Using Tilapia

- **Aquaculture Lab Reconstruction**

**The Aquaculture Research Laboratory will be reconstructed this year.**

The Dean of the College of Agriculture committed to rebuilding the Aquaculture Research Laboratory the day after an electrical fire completely destroyed the facility in November. We are well on our way toward redesign and reconstruction.

**Temporary laboratory space has been identified.**

While the lab is being constructed, we will use temporary lab space, owned and managed by Purdue, to continue our research efforts associated with the NSCORT program. We completed our inventory documentation and are in the process of replacing equipment and getting our temporary lab established. We should fully occupy it by the middle of February.

**Acquisition of fish has been arranged.**

Working with the original supplier of fish, we made arrangements for acquisition of the same genetic line of tilapia we were working with. Adult fish will be in our temporary lab by the middle of February.

11 Cary Mitchell

### Minimizing ESM for ALS Crop Production

- **Intracanopy Lighting** - The fourth hardware test with plants of the intracanopy LED array was harvested Feb. 14th. This test contained nearly twice as many plants as previous trials, and dramatically improved yield and harvest efficiency were found. Work is underway to build a mounting system that will allow us to reconfigure the lights into a planar array and use them for an overhead comparison. In addition, work is in progress on an ICES paper discussing the design of the system and the hardware tests with and without plants.

- **Sweetpotato Studies** - A sweetpotato experiment comparing single vines trained along benches, around mesh cones, and around cylinders, was harvested Feb. 23. This experiment is part of an ongoing study looking at maximizing sweetpotato yield while minimizing the volume of space occupied by vines, and will be replicated. A collaborative sweetpotato paper is being developed for ICES looking at the impact of cultivation on root yield and nutrition.

- **pH control system** - An EGC growth chamber was refurbished to allow the testing of the pH control system developed by Moeed Mukhtar and Dr. George Chiu. This control system has been tested without plants and preparations are underway to install the monitoring and control mechanisms in a hydroponics system and initiate a test with plants.

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### 12 Caula Beyl

#### Solid Waste Processing Using Edible Fungi

- Experiments were initiated to determine the enzymes and enzymatic activity of three *Pleurotus* species (*P. ostreatus*, *P. cornucopiodeae*, *P. eryngii*) in the degradation of residual plant biomass. We have begun testing rice straw, wheat straw and soybean crop residue, and will expand the test to other crop residues subsequently.
- Acquired and begun construction of a hydroponic system for routine soilless culture and production of crop biomass of lettuce, radish and strawberries.
- Prepared and submitted an abstract entitled "Edible fungal growth and fruiting on composted containerized inedible crop biomass" for a poster presentation at the American Society for Horticultural Science (ASHS) meeting scheduled for July in Las Vegas, NV.

### 13 Lisa Mauer

#### Novel Storage and Packaging Operations

##### Radiation effects on oils and antioxidants project:

- Methods have been optimized for data acquisition and needed equipment has been received.
- Preliminary radiation studies have been conducted to determine sample size, orientation, and dosage needs.
- Consultation with statistical design group will take place this month to make sure needed information can be gathered using a well-designed incomplete factorial approach.
- Radiation treatment, storage, and analysis of primary lipid and antioxidant samples beyond preliminary studies is set to begin in mid-February

##### Radiation effects on wheat project:

- Working on optimization of techniques for isolation of individual wheat components (proteins, starch, lipids, and antioxidants)
- Preliminary study indicated that radiation has effects on quality and quantity of protein (effects on starch, lipids, and antioxidants will be determined)
- Two growth cycles of wheat cultivars have been harvested from the greenhouse, and the third is set to begin in March.

##### Abstracts submitted to Institute of Food Technologists Annual Meeting:

1. J. Gandolph, J. Burgess, M. Perchonok, B. Watkins, and L.J. **Mauer**. 2005. Effects of gamma-radiation on the reducing power of antioxidants. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)
2. J. Gandolph, J. Burgess, M. Perchonok, B. Watkins, and L.J. **Mauer**. 2005. Effects of gamma-radiation on lipid oxidation and fatty acid composition. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)
3. A. Salameh, L.J. **Mauer**, and L.S. Taylor. 2005. Deliquescence lowering in mixtures of sucrose and citric acid. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)



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4. L. Snuffin, M.H. Perchonok, and L.J. **Mauer**. 2005. Food packaging waste scenarios for a mission to Mars. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)
5. A. Stoklosa, D. Nivens, and L.J. **Mauer**. 2005. Characterizing effects of Gamma Radiation on Wheat Proteins and Starches using Atomic Force Microscopy. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)

### 14 Leonard Williams Optimal Food Safety in ALS

- **Continuing Work on Determination of critical points**  
AAMU Graduate Student has completed preliminary work on determination of critical points on the surfaces of whole tomatoes. The use of pulse light sterilization as a intervention step is currently being investigated.
- **Determination of Biofilms on Surface of Tomatoes**  
Graduate student continue work on biofilm formation on salad crops and microenvironments or 'niches' created by spoilage and pathogenic bacteria. Work is currently examining the "contact strengths and angles" of Salmonella spp. on the surfaces of tomatoes.
- **Combined efficacy of pulsed light and sanitizers**  
Preliminary work to determine combined effects of disinfectants and pulsed light sterilization on inactivation of Salmonella spp. on surface of tomatoes and examines the level of penetration of pulsed light in the tomatoes.
- **Abstract prepared for upcoming meeting:**  
T. English, N. Austin and **L.L. Williams**. 2005. Efficacy of selected sanitizers on reduction of Salmonella spp. on surfaces of whole tomatoes. University and Industry Business Cluster. April, Huntsville, AL. (submitted)

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

- **Impacts of crewmember schedules on gas and water storage sizes**  
Based on constant oxygen and water resupply, and carbon dioxide removal rates, one shift and two shifts crewmember schedules are investigated to determine their effects on gas and water storage sizes, and the supply from Earth required. Then, Modified Energy Cascade dynamic crop model is integrated into the simulation. Results are compared between the two scenarios. A manuscript is in progress to report all findings and will be submitted to ICES 2005.

### 17 Julia Hains-Allen Outreach

- **Julia Hains-Allen presented the "Mission To Mars" module** to approximately 75 4-H Extension Educators, leaders and youth during a two-pronged NASA Explorer Institute held in Raleigh, North Carolina.
- **In addition, future collaborative projects between ALS/NSCORT and the two NASA/4-H focus groups were planned.**  
The two focus groups meeting simultaneously included:  
1. Extending NASA Education Resources through 4-H representatives from several state 4-H Youth Development programs will engage in focus groups to identify strategies that can improve capacities of youth professionals, volunteers, and young people to equip and inspire the next generation of



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space explorers.

2. NASA Explorer Institute: North Carolina 4-H and NASA Langley  
Using Informal Education to Revolutionize the Participation of Young  
People and Adults in the NASA Vision for Exploration and Discovery.