

Purdue University
Purdue e-Pubs

Annual and Monthly Reports

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

May 2004

April 2005 Report of Progress

James E. Alleman

Charles Glass

Jeff Volenec

Kimberly L. Jones

M. Katherine Banks

See next page for additional authors

Follow this and additional works at: <https://docs.lib.purdue.edu/alsreports>

Alleman, James E.; Glass, Charles; Volenec, Jeff; Jones, Kimberly L.; Banks, M. Katherine; Heber, Albert J.; Blatchley, Ernest R.; Applegate, Bruce; Ladisch, Mike; Brown, Paul B.; Mitchell, Cary A.; Beyl, Caula A.; Mauer, Lisa J.; Williams, Leonard; Pekny, Joseph F.; Chui, George; Yih, Yuehwern; Trimble, John; and Haines-Allen, Julia, "April 2005 Report of Progress" (2004). *Annual and Monthly Reports*. Paper 4. <https://docs.lib.purdue.edu/alsreports/4>

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

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, John Trimble, and Julia Haines-Allen



Minimizing Equivalent System Mass for an Advanced Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations

April 2005 Report of Progress

- 1 Jim Alleman** **Solid-Phase Thermophilic Aerobic Reactor (STAR) Processing of Fecal, Food, and Plant Residues**
 - The ramped solids loading to 8% was successfully achieved. Data is continuing to be collected at quasi steady-state at this loading, with a further ramping planned for early May.
 - Respirometric studies on various bench-scale parameters are continuing through May. Lignocellulose degradation is also being evaluated as part of this study.
 - Optimization of influent, operational, and HRT parameters is underway.
 - An evaluation of filtration methods is being completed in anticipation for supplementation of STAR with filtrate to enhance degradation and decrease water demands.

- 2 Charles Glass** **Nitrogen Cycling in ALS**
 - **Equipment Needs for Year 3 Experiments**

Two 5L sequencing batch reactors (SBR) will be purchased from Cole-Parmer, for a total cost of approximately \$15,000, including all peripherals. An activated sludge of 4 L of useful volume will be used in order to evaluate the nitrification followed by denitrification of the condensate water scrubbed from the gas of the STAR system. The aeration will be controlled by adjusting the air flow level to the desired oxygen concentration.

The pH will be automatically controlled by adding a solution of NaHCO₃, used as a pH buffer and carbon source for nitrifying bacteria.

The temperature will be maintained at room temperature. The reactors will be seeded with activated sludge from the Blue Plains WWTP tertiary treatment process.

Synthetic wastewater consisting of condensate water scrubbed from the gas of the STAR system will be used with the primary goal of complete conversion of ammonia to nitrogen gas.
 - **Methodology Development for Year 3**

A timer will be used to control the 24 hour SBR cycle to comprise of a fill time of 15 minutes, a mixing period of 16 hours for nitrification and 6 hours for denitrification, settling period of 1 hour and a decant time of 30 minutes. pH and dissolved oxygen will be recorded automatically on-line using a Hydra Data logger Unit. Methanol will be added in the 2 reactors at the end of the nitrification process after the DO reaches 0 mg/L. Samples will be collected for analysis during nitrification and denitrification. They will be filtered and stored at 4 °C. COD, NH₃, NO₃⁻, NO₂⁻, MLSS, and MLVSS will be analyzed following standard methods. Research has shown that zeolites increase nitrification rates in SBR's, one reactor will act as a control reactor while the other will receive clinoptilolites to confirm this enhancement.



Minimizing Equivalent System Mass for an Advanced Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations

April 2005 Report of Progress

- 3 Jeff Volenec** **Solids Separation Water Removal from STAR Biosolids Effluent Using Plants**
- We are growing and maintaining plants for dewatering experiments in preparation of STAR steady-state operation and effluent production. Dwarf cattail (*Typha minima*) and salt-tolerant cattail (*Typha angustifolia*) have been selected for inclusion because local cattail ecotypes showed a high tolerance to STAR effluent in our previous study. Vegetative multiplication of these plants is underway. In addition to these cattail species, plants of edible vegetable crops designed for NASA food production are being propagated in preparation for additional STAR dewatering evaluation using silicate-rich, coarse material that should be representative of moon and Mars regolith.
 - Germination trials are being initiated to investigate seed viability and seedling growth when STAR effluent is used as a source of water for germination. Plans to use dewatered STAR effluent solids as a plant growth substrate amendment are under development.
 - Production of several kilograms of plant material for tilapia food and mushroom growth is ongoing. These materials will be made available to programs focused on mushroom and fish growth upon request from scientists leading these research efforts.
- 4 Jim Alleman** **Liquid Freeze-Thaw (LiFT) Urine & RO Brine Processing for Advanced Water Recovery and Salt Separation**
- Experimental methods have been completed and supplies obtained for the batch freeze concentration process on the ternary (urea / NaCl / water) system. The experiments include tracking migration pathways of solutes via analysis of product water and concentrated brine streams.
 - The experiments will include NaCl, urea, antibiotic (Tylosin), and biological (E. coli) migration pathway determination.
- 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 include studying biofouling as a function of membrane surface roughness (via AFM), pore size and hydrophobicity.
 - Grafting via interfacial polymerization is being investigated as a method to reduce membrane biofouling while maintaining high flux.
 - **Reverse Osmosis/Nanofiltration Membrane System.** System is being retrofit to allow for more stable operation. Unstable pressure differences

Minimizing Equivalent System Mass for an Advanced Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations

April 2005 Report of Progress

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

- Tracer tests were conducted to determine the effects of different packing material on residence time distributions in trickling filters. Tests were performed with and without bacteria. The presence of bacteria significantly affected the residence time, almost doubling it. Average biomass per area of packing material was quantified and is correlated to residence time distribution.
- Methods were developed for analysis of a nonionic surfactant, polyalcohol ethoxylate, present in NEODOL 23-5. This surfactant is present in compact laundry detergents and dishwash detergents. A visit was made to KSC to work with Lanfang Levine on development of these methods.

7 Al Heber

Gas-Phase Revitalization Using Biofilters in ALS

Final stage of Biofiltration Lab Setup

- Finished FTIR gas analyzer calibration for methane, CO₂, *n*-butanol, ammonia, and water vapor. Will finish calibration of the other three compounds soon after we receive the calibration gases.
- Overcame the problem of condensation occurring in the steam line by applying heating tape and insulation in the steam generator to achieve a relatively stable relative humidity of 70% for the biofilter inlet air stream.
- Final touch-up of the bioreactors to optimize liquid distribution over reactor packing material. New orders are being placed to finish the experimental setup.
- Collaborative efforts with NASA Glenn Research Center are underway to evaluate the biofiltration process for gaseous trace contaminant removal under microgravity or partial gravity conditions.

Simulation of Air Quality in ALS System with Biofiltration

- Set up non-linear parameter estimation and parametric control simulation methods. These will be used to identify several model parameter values from experimental data, especially to evaluate the diffusion and biodegradation effects in the biofilters.
- Conducted a literature review on biodegradation pathways for major chemical pollutants in ALS system. Currently revising the indoor air model.

8 Chip Blatchley

Potable Water Disinfection Subject to Extended Space Travel Constraints

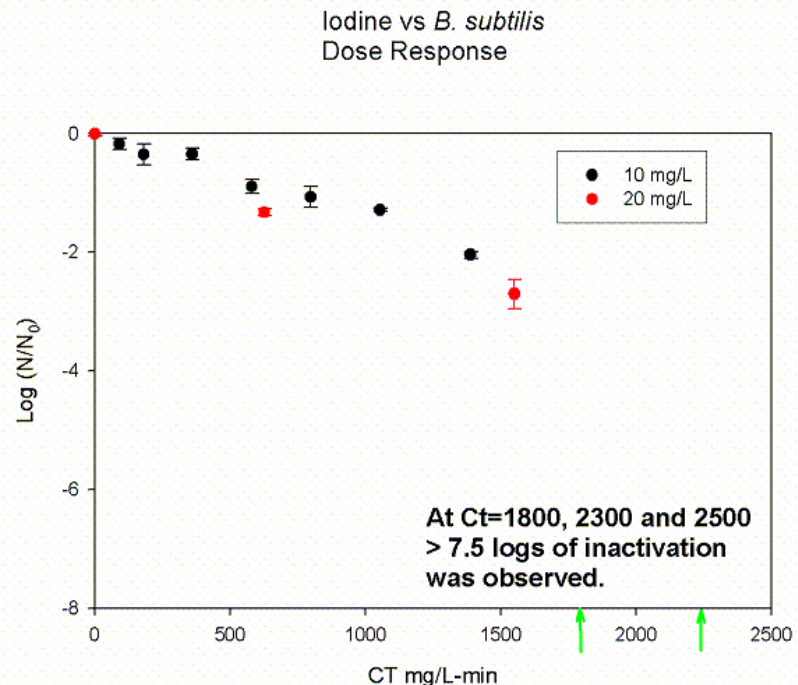
• *B. subtilis* and Iodine Experiments

Dose-response experiments were performed with iodine and *Bacillus subtilis* spores, as the challenge microorganism. Two different initial iodine concentrations were investigated. The results indicate that iodine is relatively

Minimizing Equivalent System Mass for an Advanced Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations

April 2005 Report of Progress

slow are achieving inactivation of *B. subtilis* spores (see figure below). Experiments that investigate the synergistic effect of iodine and UV in combination are in progress.



- 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.



Minimizing Equivalent System Mass for an Advanced Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations

April 2005 Report of Progress

- 10 Paul Brown** **Waste Treatment Using Tilapia**
- Collaborative efforts continue with Alabama A&M to evaluate composted residues as an improved food source for tilapia are underway. Composting is being conducted at both Alabama A&M and at the Purdue University Fish Nutrition Laboratory.
 - Beginning study to determine digestive enzymes in gastrointestinal tract of Nile tilapia fed diets containing cellulose concentrations analogous to what may be encountered in ALS residues.
- 11 Cary Mitchell** **Minimizing ESM for ALS Crop Production**
- Cary Mitchell traveled to Huntsville, AL to give an invited presentation entitled "Artificial Closed Ecosystems for Human Habitation of Space" to the University & Industry Consortium on April 14th. Gioia Massa traveled to the Space Life Sciences Laboratory at KSC to present a seminar entitled "Development of a Reconfigurable LED Plant-Growth Lighting System to Reduce Equivalent System Mass in an ALS" on April 27th.
 - ICES papers are being revised and statistical techniques are being enhanced.
 - The fifth hardware test with plants in the new lighting configuration was run throughout April. As plants near harvest we are noting inner leaf senescence and abscission. Harvest is planned for May 2. Total biomass at the end of this test will be compared with that from trial 4.
 - Studies of sweet potato, strawberry, basil, blueberry, and cranberry are continuing. New Blueberry (dwarf top hat) cranberry and lignon berry plants have been obtained and are growing well. Strawberry research in the growth chambers is wrapping up, and all cultivars are more productive under greenhouse conditions. Cowpea plants are being grown for the tilapia research group. Wheat is being grown for the food technologies group.
 - Work on the state fair exhibit is progressing, and we have obtained the parts for the demonstration hydroponic system.
- 12 Caula Beyl** **Solid Waste Processing Using Edible Fungi**
- Experiments were initiated to determine growth and fruiting of *P. eryngii* and two strains of *P. ostreatus* ('Grey Dover' and 'Pohu') on basil or sweet potato paired with wheat or rice straw at various ratios. Pairing crop residues has proven useful in degrading difficult substrates such as sweet potato and basil.
 - Continued processing additional crop residues received from the Kennedy Space Research Center, FL, for various experiments.
 - Presented a paper entitled "Using Edible Fungi to Break Down Inedible Crop Residues on Longterm Space Missions" at the 2005 Spring Meeting of the University & Industry Consortium, held in Huntsville, AL from April 13-14 2005.



Minimizing Equivalent System Mass for an Advanced Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations

April 2005 Report of Progress

13 Lisa Mauer

Novel Storage and Packaging Operations

Radiation effects on oils and antioxidants project:

- Radiation treatment, storage, and analysis of primary lipid and antioxidant samples continuing. Data interpretation is ongoing.
- Annual committee meeting held on April 14 to update Dr. Michele Perchonok and other committee members on planned research activities.
- A summer research student from Alabama A&M will join this project in June, in part, to address free fatty acid development and other oil degradation pathways. She will begin her MS degree at Purdue in August.

Radiation effects on wheat project:

- Continued working on optimization of techniques for isolation of individual wheat components (proteins, starch, lipids, and antioxidants). The method for imaging gliadin and glutenin proteins using AFM was developed, and images were collected. Data interpretation is ongoing.
- Third growth cycle of wheat continuing.
- Annual committee meeting held on April 14 to update Dr. Michele Perchonok and other committee members on planned research activities.

Outreach activity:

- The Food Science Club annual symposium was held on April 14 at Purdue. This year the topic was "Food in Space", and invited speakers were Jerry Ross (astronaut), Karen Ross (manager of food and product support at United Space Alliance), and Michele Perchonok (advanced foods lead at Johnson Space Center). Over 100 people attended, Dave Kotterman has a video of the event, and a write-up appeared on April 15 in Lafayette's Journal and Courier newspaper.

Collaborative activity:

- Will assist Dr. Lester Wilson at Iowa State University with irradiation of soybeans at space relevant levels.



Minimizing Equivalent System Mass for an Advanced Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations

April 2005 Report of Progress

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 an 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.

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

- **Use of a Markov model for health monitoring of a space system**
The lack of studies on the overall "health" of a space system (shuttle, structure, etc) has prompted the need to undertake this research. The goal of this study is to construct a model with sufficient elements to capture the "health" of the system being studied. These elements include a definition of system state, components affecting the states, state transition probabilities, failure rates of components, as well as other considerations. A Markov model was chosen for this purpose due to the stochastic nature of some processes e.g., failure of components.
3 states are defined: Safe, Transient, and Risky. The state of the system can be any of these states at any given time depending on the (relative) amount of oxygen and carbon dioxide present in the system. The components in the model that could potentially affect the level of these gases include Humans and Plants.
- **A Decision-Support System for the health monitoring system**
A decision-support system is being investigated in order for appropriate actions to be taken to bring the state of the system from Risky or Transient back to Safe. This decision-support system should also indicate whether or not a failed component is worth repairing, or if it should be replaced by a back-up system. Economic constraints as well as technological constraints will be taken into consideration. Other decisions to be made could include the type of actions that can be taken e.g., a real-time scheduling of crewmember activities, as well as other scheduling issues.



Minimizing Equivalent System Mass for an Advanced Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations

April 2005 Report of Progress

16 Julia Hains-Allen Outreach

- Presentation "Mission To Mars" National Science Teachers Association (NSTA) National Convention April 1, 2005
- NASA Booth NSTA March 30-April 3, 2005
- NASA Booth National Council of Teachers of Mathematics (NCTM) National Convention April 6-9, 2005
- Meeting with JPL Mars Bound Program at Arizona State University Mars Facility

Result: ALS/NSCORT and JPL/ASU Mars Bound Program will collaborate on production of a new version of Mars Bound to reflect manned flight. Mars Bound is an engineering module based on unmanned flight. This new collaboration will result in a Mars Bound – Manned Flight module for nationwide dissemination via ALS/NSCORT and JPL/ASU Mars Space Flight Facility.