Center for Advancing Microbial Risk Assessment
Year 6 Annual Report

Submitted to

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National Center for Environmental Research
U.S. Environmental Protection Agency (EPA)
1025 F. Street, NW, Room 3500
Washington, D.C. 20004

and

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EPA Agreement: RD832262 Center for Advancing Microbial Risk Assessment (CAMRA)
Investigators: Directors Dr. Joan B. Rose[1] and Dr. Charles N. Haas[3]; Dr. Carole Bolin[1] and Dr. Syed Hashsham[1]; Dr. Elizabeth Casman[2]; Dr. Patrick Gurian[3] and Dr. Rosina Weber[3]; Dr. Paul Keim[4] and Dr. David Wagner[4]; Dr. Mark Nicas[5]; Dr. Charles Gerba[6] and Dr. Chris Choi[6]; Dr. Joe Eisenberg[7] and Dr. Jim Koopman[7]
Institutions: [1]Michigan State University (lead), [2]Carnagie Mellon University, [3]Drexel University, [4]Northern Arizona University, [5]University of Arizona, [6]University of California at Berkeley, [7]University of Michigan

Introduction:

Under the Center for Advancing Microbial Risk Assessment, the five project teams (associated with Project I: Exposure; Project II: Infectious disease transmission; Project III: Dose-response; Project IV: Risk assessment and analysis, and Project V: Knowledge management and transfer) have completed and published a total of 44 Journal articles with 254 citations during the past six years (Figure 1). Over 18 different pathogens have been studied and described in these publications (Figure 2). As one of the most interesting categories of pathogens to EPA and DHS, Category A agents *Bacillus anthracis* (*B. anthracis*), *Yersinia pestis* (*Y. pestis*) and *Fransicella tularensis* (*F. tularensis*) have been studied extensively in over ten articles. A number of agents associated with waterborne, airborne and foodborne diseases such as *Cryptosporidium*, *E. coli*, norovirus, influenza viruses, *Mycobacterium tuberculosis* have also received significant attention.

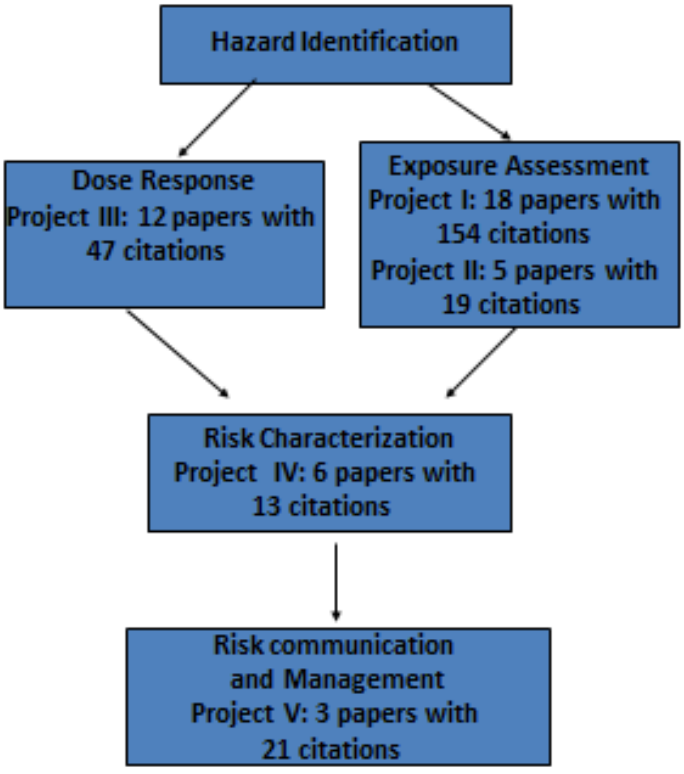


Figure 1. Risk assessment framework and the papers and citations by different projects.

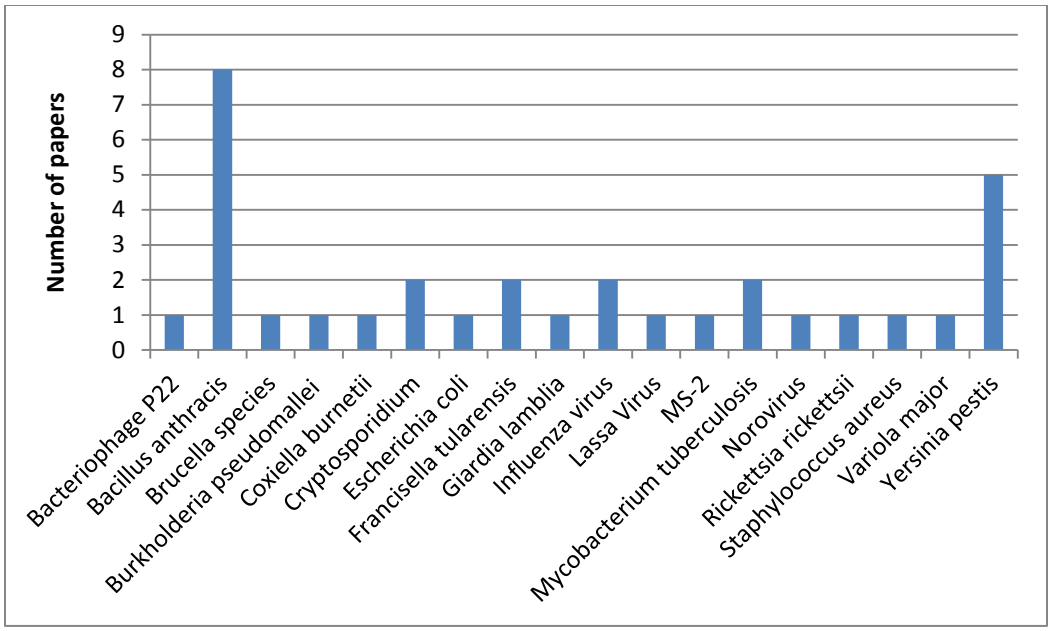


Figure 2. Number of CAMRA papers with each stated pathogen (excluding review articles).

Summary of Key Findings and Accomplishments

CAMRA's high productivity after five years has now reached an exciting level of maturity in which the frameworks and assessments are being integrated into the research by all PIs and projects. The knowledge gained has been presented to the risk community this past year through 14 publications and 14 presentations. The next generation of QMRA students are now graduating and entering the workforce. CAMRA conducted its 6th QMRA Summer institute. CAMRA will continue this high output for the coming year. Table 1 below quantifies some key accomplishments.

Accomplishment Type	Amount
Peer reviewed publications	14
Peer reviewed proceedings	3
Master's theses	3
Doctoral theses	7
Un-referred articles	1
Conference presentations	14
CAMRA workshops	2
Supported students	19
Students graduated	10

CAMRA Project I have completed their work on the transfer efficiency of *Escherichia coli*, coliphage MS-2, and *Bacillus thuringiensis* spores on various fomite surfaces i.e. Acrylic, stainless steel, Formica, glass, ceramic tile, cotton, polyester and paper money. This work addressed the significant variety of transfer efficiencies among the different fomites. Project I also completed the data analysis and manuscript preparation for the droplet spray exposure study. These data suggest that the ability to transmit infection by droplet spray exposure is highly variable across infected persons. Project I team members have used metagenomics approaches to address fomite contamination and hazard discovery for viruses.

In addition, Project I showed the usefulness of a risk assessment simulation as a way of evaluating sensor placement and tested the axial dispersion of a sodium chloride tracer passing through a cross junction to evaluate AZRED-II in comparison to both EPANET and AZRED-I.

Project II have used a deterministic differential equation based model to describe the hand and environmental mediated transmission of MRSA. Project II also conducted research on modeling influenza transmission on a college campus. Local weather variables were found statistically significantly associated with the proportion of ILI cases that tested positive for influenza virus, and the proportion of ILI diagnosis in outpatients visiting Hong Kong influenza surveillance sites.

Project III, has developed dose-response models for *Brucella* species *Leptospira* bacteria, *Rickettsia rickettsii* and Avian Influenza A (H5N1) Virus. Project III has developed the first inclusion of time post inoculation into dose response models which allows for great advancements in understanding how the body reacts to pathogen exposure and paves the way for understanding multiple dosing of pathogens effect on the host. Dose Response Models incorporating Aerosol Size Dependency were developed for *F. tularensis* and *B. anthracis*. They have also addressed *Francisella tularensis* associated with ingestion and multiple exposures.

Project IV's work on surface concentration standards for non-persistent pathogens has been a collaborative effort with Project III. Project III identified suitable dose response models and uncertainties for the effort. In addition, a review paper on persistence of Category A pathogens developed by Project I has been a key resource for this study. A joint paper with Project III has been submitted to PLOS One and received favorable reviewer comments. Project IV researchers also performed an analysis of microbial spore recovery. The use of the wipe collection method on non-porous surfaces resulted in the highest recoveries.

Project V have investigated and implemented effective and efficient methods to enhance the understanding of microbial risk assessment (MRA) as a body of knowledge. Project V has built and maintained online collaborative repository and collaborated with other projects working on an open repository. A major effort has been focused on development of the CAMRA Risk Wiki.

The CAMRA wiki, a collaborative work among all CAMRA projects, has currently been constructed as follows with Hazard and Dose-response being populated with content..
http://wiki.camra.msu.edu/index.php?title=Main_Page

- **Hazard Identification**
  - Pathogen Safety Data Sheet (PSDS)
    - Host
    - Transmission
    - Mortality Rate
    - Morbidity Rate
    - Incubation Time
    - Microbiology
    - Recommended Dose Response Models

- **Dose Response Models**
    - Summary of Data and Best Fit Model/Parameters
    - Recommended Models (based on our criteria)
    - Optimization Output for Experiments
        - Dose response data
        - Goodness of fit and model selection
        - Optimized parameters obtained from 10E+4 bootstrap iterations
        - Dose response model plot
    - Feeding Studies

- **Exposure Assessment (under development)**
    - Exposure Parameters
        - Drinking Water
            - Tap water consumption via EPA Exposure Factors Handbook
            - Treatment
                - Inactivation of microbes by free Chlorine
                - Inactivation of microbes by Chloramines
                - Reduction value by filtration
            - Pathogen Occurrence in Water Sources
                - Pathogen Concentration in Groundwater
                - Decay Rates of Viruses in Groundwater
        - Recreation Water
            - Water Ingestion by Selected Groups of Swimmers
        - Fomites
            - Recovery Efficiency
                - Recovery Efficiency from Fomites to Hand
                - Transfer Efficiencies from Hand-to-Mouth
            - Contact Rates
            - Survival on the Fomites
        - Air
    - Human Specific Parameters
        - Fecal Output
            - Pathogen Excretion Rate
- **Risk Characterization**
- **QMRA Tools**
    - Beach App
    - SMART Biosolids App

Appendix A. Summary of Project Specific Reports

Project I: Exposure: Detection, Fate and Transport of Biological Agents of Concern (BAC)
This year Project I completed their work on the transfer efficiency of *Escherichia coli*, coliphage MS-2, and *Bacillus thuringiensis* spores on various fomite surfaces i.e. Acrylic, stainless steel, Formica, glass, ceramic tile, cotton, polyester and paper money. These were assessed under two different relative humidity conditions i.e. 20 to 30% and 45 to 65%. They also expanded the work to include the Gram positive bacterium *Staphylococcus aureus*, inclusion of vaccine strains of poliovirus types 1 (Lsc-2ab) and influenza A virus. The transfer efficiency varied greatly among the different fomites (with hard surfaces such as stainless steel Fomica and acrylic plastics having the greatest efficiency of transfer, with fabrics and paper having the lowest. The differences in transfer efficiency among the different organisms were not large, but virus transfer was somewhat greater than the other organisms. MS-2 coliphage and poliovirus type 1 transfer efficiencies were very similar on the surfaces studied, indicating that it is a likely good surrogate for enteroviruses and perhaps other non-lipid containing viruses.

Project I completed the data analysis and manuscript preparation for the droplet spray exposure study. These data suggest that the ability to transmit infection by droplet spray exposure is highly variable across infected persons. Most infected persons would not transmit infection by the droplet spray route (assuming close contact with non-infected persons during coughing), but a small minority of infected persons might do so with high probability (again assuming close contact with non-infected persons during coughing). This small minority fit the concept of the "super-spreader".

Key research contributions this year also included DNA extraction from the "University of Michigan Residence Hall Influenza Study" surface samples (180 samples), PCR amplification of the 16S rRNA genes from all the samples (often this needed repetitive work due to small amount of samples and very poor quality DNA available from the specimens), amplicon purification and quality control prior to sending the amplified product to the Research Technology Service Facility (RTSF) for sequencing.

Project II: Infectious Disease Models for Assessing Microbial Risks for Developing Control Strategies
Project II used a deterministic differential equation based model to describe the MRSA exposure patterns between two patients, one colonized and the other uncolonized, residing in two separate rooms. Each room contains porous and nonporous surfaces. Nurses can transport MRSA between the rooms. MRSA transport occurred either through direct person-to-person contact or indirect contact through contaminated environment or nurses. Main findings in the baseline scenario with no interventions were as follows: 1) nurses were contaminated more from indirect contact with contaminated surfaces than direct contact with the MRSA positive patient; 2) contaminated nurses created more exposure for the uncolonized patient than did the contaminated room surfaces; and 3) the specific transfer efficiency of MRSA determined the role that surface had in transport. For example, due to the lower transfer efficiency, the porous surface maintained higher MRSA concentration levels than the nonporous surface in the MRSA-positive patient's room. However, the porous surface also transferred less MRSA to nurses.

Project II also conducted research on modeling influenza transmission on a college campus. They analyzed temporal patterns of influenza using surveillance data from a subtropical region, and considered the role of viral strain type/subtypes in identifying associations. Besides the initial annual epidemics that usually occurred between February and April, they identified a second smaller or equal-sized summer epidemic in this subtropical region based on a longer time and more reliable influenza data. Local weather variables were found statistically significantly associated with the proportion of ILI cases that tested positive for influenza virus, and the proportion of ILI diagnosis in outpatients visiting Hong Kong influenza surveillance sites. The relationships between influenza morbidity and time-lagged weather/climate variables were much stronger than non-lagged ones. The association between Absolute Humidity and influenza VPP was strongest after adjusting for other weather variables in all settings. Global climatic indicators that operate over large geographic regions were also found to be associated with observed influenza patterns.

The effects of movement patterns on flu transmission modes have been studied. To explore the dynamics of relative importance of different influenza transmission modes, an environmentally mediated agent-based mode was developed and parameterized. Human influenza transmission was modeled through four routes: fomite mediated transmission route, respiratory route, inspiratory route and droplet spray route. The analysis of model simulations has shown that the relative importance of different influenza transmission modes does vary greatly over the course of outbreaks. Specially, even in scenarios where respiratory transmission mode is ultimately dominant, non-respiratory transmission modes contribute to more to the overall transmission at the beginning of the epidemics. It takes about 10.0 days for respiratory transmissions to rise above non-respiratory transmissions. Virus particles environmental dissemination and persistence are found to be the underlying causes for these temporal dynamics of different transmission modes.

Project III: Dose Response Modeling and Application

CAMRA, via Project III, has developed dose-response models for *Brucella* species *Leptospira* bacteria, *Rickettsia rickettsii* and Avian Influenza A (H5N1) Virus. Project III has developed the first inclusion of time post inoculation into dose response models which allows for great advancements in understanding how the body reacts to pathogen exposure and paves the way for understanding multiple dosing of pathogens effect on the host. These models, generated by CAMRA researchers, allow more exact quantitative evaluation of risks based on levels of pathogens. Dose Response Models incorporating Aerosol Size Dependency were developed for *F. tularensis* and *B. anthracis*.

They have also addressed *Francisella tularensis* associated with ingestion and multiple exposures. To study the effects of single and multiple exposures to *F. tularensis*, Project III conducted a dose-response study where mice were orally infected with *F. tularensis* type A strains at various time schedules for the multiples doses. Dose-response models were developed based on the data.

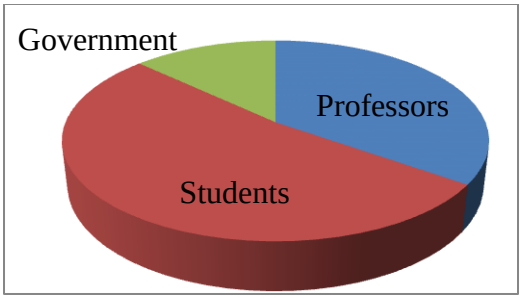
Project IV: Assessment-Analysis Interface
Project IV's work on surface concentration standards for non-persistent pathogens has been a collaborative effort with Project III. Project III identified suitable dose response models and uncertainties for the effort. In addition, a review paper on persistence of Category A pathogens developed by Project I has been a key resource for this study. A joint paper with Project III has been submitted to *PLOS One* and received favourable reviewer comments.

Project IV researchers also performed an analysis of microbial spore recovery. The use of the wipe collection method on non-porous surfaces resulted in the highest recoveries: fractional recovery (FR) = 50.4%. Lower recoveries were observed for other methods: for RMC FR was 28.7%, for swab (non-porous) FR was 2.5%, for vacuum sock FR was 1.0%. A limitation of this work is an unbalanced study design among collection methods, but it is counter-weighed by the large sample size and use of data from a realistic office building test environment.

Project V: Knowledge Management, Learning and Discover
Project V continued to improve and maintain the CAMRA Knowledge Repository. The collaborations with investigators from all Projects I through IV and their use of the system have promoted integration in a way that the group is now ready to work on a product that will be made available to all QMRA community.

Project V ran the 6th QMRA Summer Institute from August 21- August 26, 2011 at MSU, with 23 participants. Four case studies were completed including the following.

A. Safe Drinking Water for Schools:
B. High Tech Fomites Health Risks:
C. Emerging Pathogens in Commonly Eaten Food:
D. Disease Outbreaks and Natural Disasters:
   Participants came from Argentina, Brazil, Canada, Egypt, New Zealand and the USA.



Project V have investigated and implemented effective and efficient methods to enhance the understanding of microbial risk assessment (MRA) as a body of knowledge. Project V have built and maintained online collaborative repository and collaborate with other projects working on an open repository, the Camra Wiki. http://wiki.camra.msu.edu/index.php?title=Main_Page

Publications
(Peer reviewed journals)

Durham D.P.and Casman, E. A. (In Press) Threshold Conditions for Bubonic Plague Persistence in Urban Rats. *Risk Analysis*.

Solon, I., P.L. Gurian, H. Perez. (In Press) "The Extraction of a *Bacillus anthraci*s Surrogate from Pleated HVAC Filter Samples," Indoor and Built Environment.

Romero-Gomez, P., K. E. Lansey, C. Y. Choi, (In Press), Impact of an incomplete solute mixing model on sensor network design, Journal of Hydroinformatics ..

Romero-Gomez P. and C. Y. Choi, (In Press), Axial Dispersion Coefficients in Laminar Flows of Water Distribution Systems. ASCE Journal of Hydraulic Engineering.

Weir, M.H.; Razzolini, M.T.P.; Masago, Y and Rose, J.B. (In Press). Water Reclamation Redesign for Reducing *Cryptosporidium* Risks at a Recreational Spray Park using Stochastic Models. *Water Research:*

Sinclair, R. G., J. B. Rose, S. A. Hashsham, C. P. Gerba and C. N. Haas. Submitted. Selection of microbial surrogates for studying and control of pathogens in the environment. Applied and Environmental Microbiology. In revision.

Bruine de Bruin, W., Parker, A.M., & Maurer, J. (2011). Assessing small non-zero perceptions of chance: The case of H1N1 (swine) flu risks. Journal of Risk and Uncertainty, 42(2), 145-159.

Hong, T., P.L. Gurian, N.F. Dudley Ward. (2010). "Setting Risk-Informed Environmental Standards for Bacillus Anthracis Spores," Risk Analysis, 30(10):1602-1622.

Huang, Y. and Haas, C.N. (2011) "Quantification of the Relationship between Bacterial Kinetics and Host Response for Monkeys Exposed to Aerosolized *Francisella tularensis*," Applied and Environmental Microbiology 77(2): 485-490.

Kitajima, M., Huang, Y., Watanabe T., Katayama H. and Haas, C.N. (2011) "Dose-Response Time Modeling for Highly Pathogenic Avian Influenza A (H5N1) Virus Infection," Letters in Applied Microbiology. 53(4), 438–444.

Mitchell-Blackwood, J., P.L. Gurian, and C. O'Donnell, (2011) "Finding Risk-Based Switchover Points for Response Decisions for Environmental Exposure to Bacillus anthracis". Human and Ecological Risk Assessment, 17(2): p. 489-509.

Razzolini, M.T.P., Weir, M.H. Matte, M.H., Matte, G.R., Fernandes, L.N. Rose, J.B. (2011). Risk of *Giardia* infection for drinking water and bathing in a peri-urban area in St. Paulo, Brazil. *International Journal of Environmental Health Research*, 21(3), 222-234.[0]

Tamrakar S.B. and C.N. Haas. (2011) Dose-Response Model for Rocky Mountain Spotted Fever (RMSF) for Human. *Risk Analysis*.31(10), 1610-1621.

Teske S.S., Huang, Y., Bartrand, T.A., Tamrakar, S.B., Weir, M.H. and Haas, C.N. (2011) "Animal and Human Dose Response Models for Brucella species," Risk Analysis,Oct;31(10):1576-96.

(Peer Reviewed Proceedings)
Gerba, C. P. 2010. The role of fomites in transmission of pathogens in airports and on aircraft. In: Research on the Transmission of Disease in Airports and on Aircraft. Conference Proceedings 47. Transportation Research Board. National Research Council. Washington, DC.

Rosina O. Weber and Sidath Gunawardena. 2011. REPRESENTING SCIENTIFIC KNOWLEDGE. Cognition and Exploratory Learning in Digital Age (CELDA 2011). Accepted for Publication.

Sidath Gunawardena and Rosina O. Weber. 2011. BLUEPRINTS FOR SUCCESS: Recommending Characteristics of Multidisciplinary Collaboration Teams. 4th International Conference on Agents and Artificial Intelligence. Accepted for Publication.

(Book Chapters)
none

(Theses / Dissertations)
Sushil Tamrakar. Dose-Response Models of Rickettsiae and Other Biological Agents of Concern

(Un-refereed documents)
Gerba, C. P. 2011. Microbial Risk Assessment. HPC Today. 2:6-8.

Presentations
(Conference)
Austin, R. G., C. Y. Choi, P. L. Gurian, T. C. Balagopal, 2010, Event-Based Microbial Risk Assessment and Response Analysis of Cryptosporidium in Municipal Water Distribution Networks, Water Distribution Systems Analysis (WDSA), Tucson, AZ.

Andrade, M. A., F. Rojano, P. Romero-Gomez, and C. Y. Choi, 2010, Integrated Water Quality Modeling of Water Distribution Systems, Water Distribution Systems Analysis (WDSA), Tucson, AZ.

Poster presentation at the 111Th General Meeting of the American Society for Microbiology, May 20-24 2011, titled "Genetic Characterization of Microorganisms on Highly Touched and Untouched Fomites" (LU 1251, Amanda Herzog)

Syed Hashsham. Biochip Analysis for Microbial Detection, On-chip PCR, Bioindicators for Pathogens. Recent Advances in Microbial Control: Society for Industrial Microbiology Meeting; Arlington, VA. 11-10-2010.

Syed Hashsham. DNA Microchips for Detection of Microorganisms in Water & Food Samples. TECAN Symposium 2010 in Salzburg, Austria: Applying Genomic Technologies. 10-08-2010.

Allen, C.A., D. Birdsell, D.L. Greenberg, E.P. Price, D.S. Sarovich, S. Wolken, A. Hurbon, P. Keim, and D.M. Wagner. Identification of *Bacillus anthracis* surrogates in experimental releases for risk assessment. Annual Meeting of the Arizona-Nevada Branch of the American Society of Microbiology, Flagstaff, Arizona, April 2011 (Talk).

Gerba, C. P. June 30, 2011. “The role of fomites in disease transmission in indoor environments”. Arizona Environmental Health Association”. Phoenix, AZ.

Huang, Y., Verhougstraete, M.P.and Rose, J.B. "Microbial water quality assessment for Great Lakes in Michigan: Relationship between water quality, weather and emergency room visits," Poster presented at the Singapore International Water Week, Singapore, July 4-7, 2011.

Tao Hong and P.L. Gurian, "A Bayesian Monte Carlo approach to model calibration for weaponized B. anthracis fate and transport", in Society for Risk Analysis 2010 Annual Meeting. Salt Lake City, UT, December 2010.

Mitchell-Blackwood, J. and P.L. Gurian, “Bayesian model comparison of dose-response models for biological agents,” Society for Risk Analysis 2010 Annual Meeting, Salt Lake City, UT, December 2010.

Tao Hong and Patrick Gurian. "A Bayesian Approach to Model Calibration for Weaponized B. Anthracis Risk Assessment", in U.S. Department of Homeland Security University Network Summit and Student Day, Washington DC, March, 2011.

Gurian, P.L. and T. Hong, “Uncertainty in Quantitative Microbial Risk Assessment Models”, invited seminar Villanova University Department of Civil and Environmental Engineering, January 21, 2011.

Huang, Y. and Rose, J.B. "Quantitative Microbial Risk Assessment," ”, invited seminar, Nanyang Technological University, Singapore, July 15, 2011.

Huang, Y. and Rose, J.B. "Quantitative Microbial Risk Assessment," ”, invited seminar, National University Of Singapore, Singapore, July 11, 2011.

Workshops

Heather Galada, Charles Gerba, Alrica Joe, Arun Kumar, Elia Marquez, Mira S. Olson, Ian Pepper, Evan Richter, Jingjie Teng, and Patrick L. Gurian. 2011. “Teaching Quantitative Microbial Risk Assessment in Environmental Engineering & Science,” Association of Environmental Engineering and Science Professors, University of South Florida, Sunday July 10, 2011.

(CAMRA Workshops)

6th QMRA Summer Institute, Michigan State University, East Lansing, MI, August 2011.

Appendix B. Knowledge Repository Summary Reports

CAMRA Report for Year VI (September 15, 2010 to September 14, 2011) for Project I

1. Project I

2. Investigators: Christopher Choi, Mark Nicas, David Wagner, Paul Keim, Ian Pepper, Syed Hashsham, Ryan Sinclair, Sonia Fankem, Tomoyuki Shibata, Rachael Jones, David David Greenburg , Scott McLennan , Pedro Romero, Ryan Austin, Yoshifumi Masago, Stephanie Boone, Amanda Herzog, Jessica Henley, Inhong Song, Alok Pandey, William McGarry, Andrew Lerch, Leilei Qian, Joan Rose, Charles Gerba

3. Project Goals:
   Development and validation of surrogates for bioterror agents.
   Development and validation of models for the survival, recovery, fate, and transport of infectious agents in the environment.

4. Tasks for Year IV (September 15, 2008 to September 14, 2009):

Dr. Charles P. Gerba's Laboratory (UA):

Data on the transfer efficiency of microorganisms from fomites to hands, survival on hands and transfer of microorganisms is needed for models which describe the exposure of persons in indoor environments via contaminated fomites. Such information can also be used in models to assess the success of interventions, such as, hand sanitizers, long lasting disinfectants, self-sanitizing disinfectants, etc. Data on the transfer efficiency of bacteria, viruses and spores from different surfaces is very limited and this project seeks to development more quantitative data under defined conditions which can be used in indoor exposure models. Data on the survival on hands is also needed.

This year we completed our work on the transfer efficiency of *Escherichia coli*, coliphage MS-2, and *Bacillus thuringiensis* spores on various fomite surfaces i.e. Acrylic, stainless steel, Formica, glass, ceramic tile, cotton, polyester and paper money. These were assessed under two different relative humidity conditions i.e. 20 to 30% and 45 to 65%. We also expanded our work to include the Gram positive bacterium *Staphylococcus aureus*, inclusion of vaccine strains of poliovirus types 1 (Lsc-2ab) and influenza A virus. The transfer efficiency varied greatly among the different fomites (with hard surfaces such as stainless steel Fomica and acrylic plastics having the greatest efficiency of transfer, with fabrics and paper having the lowest. The differences in transfer efficiency among the different organisms were not large, but virus transfer was somewhat greater than the other organisms. MS-2 coliphage and poliovirus type 1 transfer efficiencies were very similar on the surfaces studied, indicating that it is a likely good surrogate for enteroviruses and perhaps other non-lipid containing viruses.

The viability of both MS-2 coliphage and *E. coli* inoculated onto fingertips did not decease significantly on fingertips after 30 minutes.

Dr. Christopher Choi's Laboratory (UA):

Effects Of The Axial Dispersion Coefficients In Water Distribution Systems and update AZRED. Water quality models of pressurized water distribution systems can be improved by including the transport phenomena that accurately represent mixing at junctions and axial dispersion, thereby representing the solute transport within distribution networks. Previous computational and experimental studies have supported the assumption that mixing at junctions is incomplete rather than complete, as has been conventionally assumed. In addition, a recent study proposed, and experimentally verified, that dispersion coefficients could be used effectively in pipelines under laminar flows. The present work incorporates axial dispersion transport into an enhanced water quality solver (AZRED) that already accounts for incomplete mixing at four-way junctions. First, hydraulic calculations in a selected network will provide the database for water quality simulations that involve incomplete mixing at junctions. Next, a 1D dispersion-advection model, integrated with recently developed coefficients, will produce transient water quality results for the network. The results will be quantitatively compared with those obtained based on the conventional assumptions; i.e., complete mixing and advection-only solute transport. We will then embed axial dispersion into the AZRED code in order to fully integrate both of the improved transport assumptions for water quality analyses. We will present the outcomes we have obtained from using a balanced approach that combines Computational Fluid Dynamics (CFD) simulations, experiments, and modeling. The broad goal of this research is to emphasize the importance of the water quality modeling that utilities use to obtain the predictions they need in order to make pressing decisions, such as those pertaining to operation, microbial risk assessment, and the early warning systems designed to detecting contamination events

Dr. David Wagner's Laboratory (NAU):

Conduct several short term survival studies involving side-by-side comparisons of fully virulent Bacillus anthracis strains from phylogenetically diverse groups and Bacillus surrogates. Analyze results generated from the previous short and long term studies on surrogates and prepare scientific publications.

Dr. Syed Hashsham's Laboratory (MSU):

1. Genetic characterization of highly touched and untouched fomites using 454 sequencing.
   Evaluation and characterization of bacterial samples collected from the fomite surfaces in dormitories at the University of Michigan by sequencing 16S rRNA genes using 454 FLX sequencing technology. Primers will be designed to target conserved regions surrounding hyper-variable regions of relevant genes, and amplicons will be used for sequencing. Signature sequences found with 454 Sequencing Technology will show the presence of organisms from the fomite samples.
2. Detection limits of all methods for influenza, norovirus, and MRSA
   Literature from published journal articles on the detection methods for influenza, norovirus, and MRSA will be reviewed. Journal articles will be collected using a number

of key words on ISI Web of Science. References will be exported into an EndNote file. A manual screening will be conducted to eliminate any references that were not expected to contain relevant data.

3. Improvement of risk assessment for *Bacillus anthracis* experimentally

The model used in the manuscript, Implications of Limits of Detection of Various Method for *Bacillus anthracis* in Computing Risks to Human Health, was simplistic due to insufficient data sets in the literature. The risk assessment approach presented in the manuscript could be further improved if an experimental probability distribution of the estimated dose (x) was available. However such a probability distribution was not available even for the most common matrix (soil). To obtain such a distribution, a large number (e.g., 30) of different true doses (d) must be spiked in the environmental matrix of interest and the sample processed through an entire protocol. This time-consuming process has not yet been reported. For this evaluation, *Bacillus thuringiensis* (surrogate for *Bacillus anthracis*) will be spiked into soil and water samples.

4. Digital LAMP as a Method to Address the Issue of Environmental Detection Limit.
   Our survey of environmental detection limit, published in the journal Applied and Environmental Microbiology "Implications of Limits of Detection of Various Method for *Bacillus anthracis* in Computing Risks to Human Health" also highlighted the need to develop methods capable of detecting much lower concentrations of threat agents. One of the novel methods/approaches used is called digital PCR (Which is akin to caring out a most probable number analysis but in nanoliter real time PCR chambers). When combined with the method that is known for better limit of detection (isothermal amplification), such an approach has the potential to improve the environmental detection limit by at least 100-fold. The goal of digital LAMP approach is to experimentally test this hypothesis.

Dr. Mark Nicas' Laboratory (UC Berkeley):

Note: The official start date of the sub-award for UC-Berkeley was September 1, 2005, but grant funds were not available at UC-Berkeley until April 20, 2006. The result is that while Year 4 officially covers the period of September 1, 2008 through August 31, 2009, in practice it covers the period from April 20, 2009 through April 19, 2010.

Task 1: Markov chain model

Draft a manuscript reporting the performance of the Markov chain model in predicting particle deposition in the chamber. We have drafted a manuscript describing the experimental particle deposition data, and a manuscript describing the experimental time-to-mixing and anenometry data. The draft manuscript of the particle deposition data is in second review. In addition, a colleague of Dr. Haas at Drexel University may be able to simulate particle deposition in the test chamber via CFD modeling, such that we can compare the performance of the Markov chain and CFD methods.

Task 2: Droplet Spray Exposure

This is a continuation of a project started in Year 3. A major pathway for person-to-person infection with respiratory tract pathogens (for example, smallpox virus, pneumonic plague *Y. pestis*, influenza A virus) is thought to involve "droplet spray" exposure. For this transmission mode, large particles (primarily of noninspirable

diameters) are emitted as projectiles via a cough or sneeze, and strike target facial membranes (the conjunctivae, nostrils, lips) of a person located within three feet of the infector. However, there are no published studies that have examined exposure potential via this route. We propose to investigate this potential in a straightforward manner. A panel of human subjects will cough at pieces of sample paper (for example, 0.7 m × 0.7 m) which contain outlined features of the eyes, nostrils and lips. The chloride content of the three target sites and of the rest of the paper will be eluted, and the chloride ion concentration will be measured. The proportion of each subject's cough projectile volume that strikes each of the target membranes will be estimated.

A sodium chloride solution in several mL water will be introduced into the mouth for mixing into saliva prior to the cough. The effect of distance between the subjects and the sampling paper will also be determined.

Task 3: Choreographed Tests of a Model for the Fomite-Mediated Dose

Based on first principles, a simple model is formulated for the expected number of pathogens transferred onto an individual's fingertip(s) via touching contaminated room surfaces. The inputs are the average pathogen concentration on the surfaces being touched C (# per cm^2), the area of the room surface contacted per touch A (cm^2 per touch), the rate of touching room surfaces H (touch per hour), the transfer efficiency from the touched surface to the fingertip ε_1 (a fraction between 0 and 1), the transfer efficiency from the fingertip back to a touched surface ε_2 (a fraction between 0 and 1), and the duration of the process T (hour). Without regard to pathogen die-off, and assuming no overall change in C due to touching, the number of pathogens on the fingertip at the end of $n = H \times T$ touches, denoted D, is:

Eq. (1) $$D = \varepsilon_1 \times C \times A \times \sum_{i=1}^{n} (1-\varepsilon_2)^{n-i}$$

If the pathogen concentrations differ between the touched surfaces and are predetermined, the dose algorithm is modified as follows:

Eq. (2) $$D = \varepsilon_1 \times A \times \sum_{i=1}^{n} C_i \times (1-\varepsilon_2)^{n-i}$$

The intention is to "choreograph" sequences of touches by one or more individuals to examine the validity of predicting D by Equation (2). A non-pathogen such as a bacteriophage or influenza vaccine strain virus would be used, and the agent would be assayed by a plaque assay (for a phage) and/or quantitative polymerase chain reaction. For example, known numbers of virus would be seeded onto three demarcated areas 1 cm in diameter such that the respective concentrations are C_1, C_2 and C_3. Using the same fingertip, a subject would enact the following sequence: (1) touch the first seeded area; (2) touch two clean areas; (3) touch the second seeded area; (4) touch two clean areas; and (5) touch the third seeded area. The predicted dose on the fingertip is:

Eq. (3) $$D = \varepsilon_1 \times A \times \left(\left[C_1 \times (1-\varepsilon_2)^4 \right] + \left[C_2 \times (1-\varepsilon_2)^2 \right] + C_3 \right)$$

An important set of choreographed sequences is having a subject touch one or more areas that were previously touched by a different subject with a contaminated fingertip. That type of experiment directly examines the ability of fomite-mediated pathogen transfer between individuals.

As part of this task, a choreographed sequence using an influenza vaccine strain virus would be designed in conjunction with Mr. Ian Spicknall (PhD candidate) and Dr. Joe Eisenberg at the University of Michigan to test Mr. Spicknall's virus dosing model with regard to fomite transfers. As part of the work of CAMRA Group 2, Mr. Spicknall is developing a computer model that explicitly incorporates interactions between individuals including the touching of common surfaces. Any pre-determined sequence of touching common surfaces is simply a choreographed sequence as described here. Thus, a choreographed sequence experiment can be used to investigate the validity of a key part of Mr. Spicknall's model.

Task 4: Field Investigation of Influenza Virus in Patient Rooms

The intent is to conduct a pilot study of influenza virus concentrations on surfaces in influenza patient rooms, and on the disposed gloves and respirator filter media of health care workers (HCWs) who attend these influenza in-patients. The study would be conducted at a University of California, San Francisco, hospital in conjunction with Robert Harrison, MD, MPH. Dr. Harrison is a UC-SF faculty member in Occupational and Environmental Medicine, and Chief of the Occupational Hazard Surveillance and Evaluation Program at the California Department of Public Health. At UC-SF, admitted patients with confirmed influenza (A or B) are placed in negative-pressure, single-occupancy rooms. HCWs entering the patient rooms are required to wear disposable gloves and a disposable N95 filtering-facepiece respirator.

By prior arrangement, the hospital Infection Control Officer would inform Dr. Harrison of the admission of a confirmed influenza patient. An investigator would go on site and spend one or more shifts in the department housing the patient. By prior arrangement, the investigator would collect the gloves and filtering-facepiece respirator that are discarded by a HCW (a nurse) after attending to the influenza patient. At least three sets of gloves/respirators would be collected from one or more HCWs. In addition, swipe samples of nonporous room surfaces close to (e.g. a bedside table) and far from (e.g., the top of a television cabinet) the patient's bed would be collected. In addition, swipe samples of porous surfaces (e.g., bed coverings) would be collected. The swipes would be collected while the patient was out of the room, or might be collected by one a hospital staff member (e.g. Dr. Harrison) while a HCW was attending the patient. Some swipe samples would be collected on surfaces outside the patient's room.

The environmental samples would be shipped to Dr. Gerba's laboratory at the University of Arizona. Virus (if present) would be eluted from the fingertip portions of the gloves, from cutout sections of the respirator filters, and from the swipe samples, and assayed by quantitative polymerase chain reaction. Quality control samples (unused gloves and respirators, unused swipe materials) would be included.

The goal is to conduct this environmental virus prevalence monitoring for three to six influenza patients. The exact number depends in large part on the future number of admitted patients, which is uncertain. The expectation is that influenza virus would be found on room surfaces, but perhaps not on respirator filter media, because most virus emitted via coughing is carried in large particles that settle rapidly from room air. However, finding virus on the respirator filter media is suggestive evidence for airborne transmission, and finding influenza virus on glove fingertips is suggestive evidence for fomite-mediated transmission. Moreover, any positive findings would support applying for other funding to conduct a larger study including air sampling inside and outside patient rooms, more extensive swipe sampling inside and outside patient rooms, and nasal swabbing of HCWs. An epidemiological study of influenza incidence among HCWs is not feasible, because the UC-SF hospital actively promotes seasonal vaccination for all its HCWs.

Note on Human Subjects Review and Approval

At present, Mark Nicas has approval from the UC Berkeley Committee for the Protection of Human Subjects (CPHS # 2008-1-40) for the droplet spray exposure study (proposed Task 2), and has requested an extension for one year. Prior to engaging in any human subject work for the choreographed sequence tests (proposed Task 3) and the field investigation study (proposed Task 4), approval will be obtained from the UC Berkeley CPHS. However, for each of the latter two studies, there is preliminary laboratory work that must be conducted prior to any work involving human subjects.

5. Summary of Research Activities

Researcher Name	Research Activities
Christopher Choi	Evaluating risk assessment
Pedro Romero	Identifying contamination
Ryan Austin	Analyzing water distribution
Amanda Herzog	Analyzing microbial dispersion data Analyzing Availability of DNA Determining Inactivation Investigating surrogates Evaluating detection limit
Charles P. Gerba	Generating transfer data Conducting exposure assessments
Mark Nicas	Analyzing risk assessment Modeling Transfer Testing models Measuring exposure Modeling fate and transport

6. Background and prior research:

7. Research Contributions this Year:

1. Digital LAMP used for Evaluation of P22 Recovered from Fomites Things that are in progress LU (1259)
   Author(s): Amanda Herzog
   When Evaluating detection limit we wanted to find out Determining method capabilities from P22 recovered at the detection limit.
   Experimental Design was as follows:
   This task involves an experimental evaluational of digital LAMP method using P22 recovered from fomites at the detection limit. The method of recovery will be cotton swabs. One of the novel methods/approaches used is called digital PCR (Which is akin to caring out a most probable number analysis but in nanoliter real time PCR chambers). When combined with the method that is known for better limit of detection (isothermal amplification), such an approach has the potential to improve the environmental detection limit by at least 100-fold. The goal of digital LAMP approach is to experimentally test this hypothesis.

2. Quantum dots as surrogates for microorganisms (800,1249)
   Things that are in progress LU 800
   Author(s): Amanda Herzog
   and Things that I have completed LU 1249
   Author(s): Amanda Herzog
   When Investigating surrogates we wanted to find out Suitability of quantum dots as a surrogate for microorganisms.
   Experimental Design was as follows:
   The work on evaluation of quantum dots as surrogate involves identification of characteristics of all types of quantum dots and theoretical evaluation of QDs for use as surrogate followed by an experimental validation of its usefulness. Literature review suggests that it has good potential but its use as surrogate will require further evaluation and development. Major criteria selected for a suitable surrogate are size, detection limit, cost, measurement techniques and toxicity.
   Contribution:
   Evaluation of their characteristics has shown their potential as surrogate for pathogenic microorganisms. Further applications in this direction will depend on their cost and efficient detection methods.
   Results:
   Potential applications of QDs such as rapid and sensitive microbial and toxin detection, enhancement of PCR specificity with different types of QDs, and surrogates for pathogens and chemicals are presented. Also, experimental evidence of the DNA damage due to polyethylene glycol-coated CdSe-ZnS quantum dots on human lymphocytes is provided. Quantum dots could be toxic to DNA in concentrations ranging between 10-100 nM with 3-6 hour of exposure. Environmental applications could lead to the discharge of quantum dots in the environment. Here the effects of natural organic matters on quantum dot-partitioning to the environment are discussed. In general, use of quantum dots is envisioned for many environmental applications but a critical evaluation of the capabilities, advantages, and disadvantages or limitations is missing. Often quantum dots are presented as a panacea for all environmental applications where detection limit and particle tracking are being pursued. This review critically presents the capabilities and some of the already identified limitations.

   Test Chlorine Residual on Fomites After Sterilization (1263,1264)
   Things that are in progress LU 1263
   Author(s): Amanda Herzog
   and Things that I have completed LU 1264
   Author(s): Amanda Herzog
   When Testing contamination we wanted to find out To determine if there were any chlorine residual on the fomites after sterilization which would affect the recovery and survival of Bacillus anthracis.
   Experimental Design was as follows:
   A standard curve from 0.05 to 4 mg/L of total chlorine will be generated. Washing of fomites (acrylic, steel, and laminar) which included rinsing with water will be simulated. Using DPD Total Chlorine Reagent the water that rinsed

the each fomite will be test for chlorine residual. Another experiment tested the chlorine residual without the rinsing step. Each experiment will be done in triplicate.
Contribution:
Total chlorine residual remains after the fomite is sterilized which could affect recovery and survival of Bacillus anthracis on fomites.
Results:
When simulating the washing and rinsing step the average total chlorine residual was 0.31 mg/l on laminar, 1.60 mg/l on steel and 0.09 mg/l on acrylic. When eliminating the rinsing step the average total chlorine residual was 11.3 mg/l on laminar, 4.21 mg/l on steel and 13.74 mg/l.

3. Combined water quality model using mixing and dispersion (877,58)
   Things that are in progress unit Number 877
   Author(s): Christopher Choi
   and Things that I have progress unit Number58
   Author(s): Rosina Weber
   Initially Modeling transport phenomena we wanted to find out What the most effective search method for learning units is
   The original Experimental Design was as follows:
   What the most effective search method for learning units is
   We are currently trying to find out At present, the prevailing network water quality models are based on two major simplifications. First, solute mixing is assumed to be complete and instantaneous at the pipe junctions. Second, longitudinal dispersion of the solute mass along the pipe axis is ignored, and plug flow is assumed to prevail. However, our recent investigations clearly show that these assumptions are not valid for a wide range of conditions that commonly exist in real pipe networks.
   The current Experimental Design is as follows:
   1. Evaluate junction mixing and axial dispersion separately. 2. Combine both effects through a single junction. 3. Combine both effects through multiple junctions. 4. Conduct experimental verification. 5. Build contamination scenarios.

   Detection Limits All Methods for Influenza, Norovirus and MRSA (1247,909)
   Things that are in progress unit Number 1247
   Author(s): Amanda Herzog
   and Things that I have progress unit Number909
   Author(s): Amanda Herzog
   Initially Evaluating detection limit we wanted to find out The detection limit for all methods detecting influenza
   The original Experimental Design was as follows:
   The detection limit for all methods detecting influenza
   We are currently trying to find out The detection limit for all methods detecting influenza, norovirus and MRSA and the risk estimates at the methods detection limit.
   The current Experimental Design is as follows:

Literature from published journal articles on the detection methods for influenza, norovirus and MRSA will be reviewed. Journal articles will be collected using a number of key words on ISI Web of Science. References will be exported into an EndNote file. A manual screening will be conducted to eliminate any references that were not expected to contain relevant data.

Detection Limits All Methods for Influenza, Norovirus and MRSA (1247,1083)
Things that are in progress unit Number 1247
Author(s): Amanda Herzog
and Things that I have progress unit Number1083
Author(s): Amanda Herzog
Initially Evaluating detection limit we wanted to find out The detection limit for all methods detecting respiratory and foodborne viruses and the risk estimates at those detection limits.
The original Experimental Design was as follows:
The detection limit for all methods detecting respiratory and foodborne viruses and the risk estimates at those detection limits.
We are currently trying to find out the detection limit for all methods detecting influenza, norovirus and MRSA and the risk estimates at the methods detection limit.
The current Experimental Design is as follows:
Literature from published journal articles on the detection methods for influenza, norovirus and MRSA will be reviewed. Journal articles will be collected using a number of key words on ISI Web of Science. References will be exported into an EndNote file. A manual screening will be conducted to eliminate any references that were not expected to contain relevant data.

454 Sequencing of Highly Touched and Untouched Fomites in a Dorm (1254,1086)
Things that are in progress unit Number 1254
Author(s): Amanda Herzog
and Things that I have progress unit Number1086
Author(s): Amanda Herzog
Initially Analyzing Availability of DNA we wanted to find out The genetic characterization of background bacterial populations on touched and untouched surfaces as illustrated by their 16S rRNA gene.
The original Experimental Design was as follows:
The genetic characterization of background bacterial populations on touched and untouched surfaces as illustrated by their 16S rRNA gene.
We are currently trying to find out The genetic characterization of background bacterial populations on touched and untouched surfaces as illustrated by their 16S rRNA gene.
The current Experimental Design is as follows:
DNA was extracted from 180 samples taken from highly touched and untouched fomites in dormitories at the University of Michigan. All 180 samples were amplified with PCR, run on a gel, and purified with PCR purification kit. 16S

rRNA genes were amplified by using universal primers with 454 associated tags. Primers were designed to target conserved regions surrounding hypervariable regions of relevant genes, and amplicons were used for sequencing. There were 88 samples that had positive results and were submitted to Research Technology Support Facility (RTSF) for the sequencing on the Roche 454 GS-FLX system.

4. Test Chlorine Residual on Fomites After Sterilization (842,1263)
   Things that are in progress unit Number 1263
   Author(s): Amanda Herzog
   and Things that I have completed unit Number 842
   Author(s): Amanda Herzog
   Once we learned:
   We showed the variability of B. thuringiensis recovery as a function of surface type, surface area, recovery time, recovery method and wetting agent.
   This result led us to the following research question Testing contamination we wanted to find out To determine if there were any chlorine residual on the fomites after sterilization which would affect the recovery and survival of Bacillus anthracis.
   The current Experimental Design is as follows:
   A standard curve from 0.05 to 4 mg/L of total chlorine will be generated. Washing of fomites (acrylic, steel, and laminar) which included rinsing with water will be simulated. Using DPD Total Chlorine Reagent the water that rinsed the each fomite will be test for chlorine residual. Another experiment tested the chlorine residual without the rinsing step. Each experiment will be done in triplicate.

   Advanced statistical analysis (116,1270)
   Things that are in progress unit Number 1270
   Author(s): Amanda Herzog
   and Things that I have completed unit Number 116
   Author(s): Amanda Herzog
   Once we learned:
   We showed the variability of P22 recovery as a function of surface type, humidity, application mediums, wetting agent, and the surface area.
   This result led us to the following research question Analyzing recovery we wanted to find out To understand the variability of P22 recovery as a function of surface type, humidity, application mediums, wetting agent, and the surface area.
   The current Experimental Design is as follows:
   Further analysis of the recovery of P22 from fomites data using an incomplete multifactorial design. Statistical analysis will be conducted with SAS and assistance from the Center for Statistical Training and Consulting (CSTAT).

   MS Revision (1053,1286)
   Things that are in progress unit Number 1286
   Author(s): Amanda Herzog
   and Things that I have completed unit Number 1053

Author(s): Amanda Herzog
Once we learned:
We showed the variability of recovery and survival of bacteriophage P22 and B. thuringiensis on fomites as a function of fomite type, fomite surface area, application media, relative humidity, wetting agent, recovery materials, time of sampling, and detection method.
This result led us to the following research question Revising materials we wanted to find out We showed the variability of recovery and survival of bacteriophage P22 on fomites as a function of fomite type, fomite surface area, application media, relative humidity, wetting agent, recovery materials, time of sampling, and detection method.
The current Experimental Design is as follows:
Revisions to the manuscript titled "Evaluation of Recovery and Survival of P22 on Fomites" submitted to Journal of Applied Environmental Microbiology are being addressed based on the reviewers comments.

LU 1242: Multiobjective Sensor Placement with Improved Water Quality Model
Contributor: Christopher Choi
Results:
Optimal locations for sensor placement in a simple network and under both perfect and imperfect mixing conditions were determined using the multiobjective approach. Differences between the two approaches are much more apparent in the 5 X 5 grid network than when testing example Network 3. This is due to the limited number of locations in Network 3 where imperfect mixing takes place, only two of which are cross junctions (the type of junction where the least amount of mixing takes place). For the 5 X 5 network, differences between EPANET and AZRED based optimizations were significant. Differences are especially dramatic when redundancy is used as a metric of sensor placement choice. It is hypothesized that because of the competitive nature of the different objective functions, that Pareto optimal solutions result in placements where the redundancy condition is just met. Optimization based on a less detailed model can, therefore, result in placements which are not close to optimal. Likelihood of detection and detection time were not as sensitive to the water quality model but still resulted in significant differences between the two models (AZRED and EPANET) which would likely result in different decisions being made by the sensor designer. Network 3 resulted in sensor designs that had some differences (between AZRED and EPANET) in sensor location. Although the sensor locations were different and were no longer optimal when changing to AZRED, the locations based on EPANET were still near optimal. This indicates that little would be gained by using AZRED as the water quality model for optimizing sensor placement design for Network 3. The use of AZRED is most important with networks that have many cross junctions, and in this case, an imperfect mixing model will influence sensor placement. The differences seen between sensor placements based on AZRED and those based on EPANET are highly dependent on the objective functions. In the case where a network includes many cross junctions and the design criteria is sensitive to concentrations throughout the network, imperfect mixing is important for a good design.

LU 1243: Event-Based Microbial Risk Assessment and Response Analysis of Cryptosporidium
Contributor: Christopher Choi
Results:
A framework for an event-based risk assessment model of water distribution networks is proposed. This is achieved by describing the portions of the network that are most vulnerable to these contaminations as the portions that should be the focus of those wishing to protect a distribution network from contamination. Sensor placement methods are also investigated, as an evaluation of the effectiveness of different sensor placement schemes. This shows the usefulness of a risk assessment simulation as a way of evaluating sensor placement. It is shown (for the tested network) that more weight should be given to maximizing the likelihood of detection by placing sensors at optimal locations, rather than by shortening the expected time until detection. It is also shown that optimal sensor placement accomplished using this criterion produces better protection than does increasing the number of sensors. It is strongly suggested that other multiobjective functions for sensor placement be examined using risk assessment to ensure that in addition to the direct tradeoff between the optimization functions, the tradeoff in terms of a health risk assessment impact is understood. These findings should be beneficial to utilities planning to install or refine sensor networks. This should also encourage rigorous sensor network design as a cost effective way to reduce the impact of contaminants in a network. If secondary analysis using a risk assessment model is not practical, then coverage as a criterion works well as a single objective decision parameter.

LU 1244: Experimental Verification of Combined Axial Dispersion and Incomplete Mixing
Contributor: Christopher Choi
Results:
To evaluate AZRED-II in comparison to both EPANET and AZRED-I, the axial dispersion of a sodium chloride tracer was tested as it passed through a cross junction: The phenomena of both axial dispersion and incomplete mixing were observed together. AZRED-II predicted the spatiotemporal solute patterns traveling through a cross junction and pressurized pipes far better than EPANET or AZRED I. The experimental trials and corresponding outcomes clearly indicate that AZRED-II accurately represented the physical behavior of solute transport phenomena. Testing was also conducted on a small network patterned after EPANET's example network 1. The system was built to include two cross junctions as well as three 90-degree elbows downstream from the tracer injection location. More significant differences were observed between the predicted arrival of sodium chloride and the data readings than were observed in the previous tests. It was surmised that these differences arose because the network was more complicated (it included more cross junctions and bends). Despite these differences, the AZRED-II model appeared to achieve a significant improvement in accuracy over the other models tested; i.e., AZRED-II was a better predictor of peak concentration, arrival time, and duration. Thus, the findings of the present study support the use of AZRED-II as a tool for improving the modeling of the laminar portions of distribution systems. AZRED-II should provide a significant improvement when modeling processes in which timing and peak concentration prediction are important, or more generally speaking, anytime a more accurate spatiotemporal resolution of a constituent in the distribution system is desired. The program should also prove valuable in assessing risk whenever arrival time, duration, and concentration

of contaminants in the network become critical. AZRED-II could also help to more accurately determine optimal sensor placement and to develop the backtracking algorithms needed to find contaminant intrusion locations. AZRED-II should also work well in traditional water quality simulations, such as predicting disinfectant levels throughout pressurized pipe systems. All of these practices would benefit from the more accurate predictions of arrival times, durations, and concentrations that can be obtained using AZRED-II, which is the first program to address the behaviors of imperfect mixing and axial dispersion together. Further studies should seek to understand axial dispersion in transitional and turbulent flow regimes.

Contributor: Charles P. Gerba and Ian L. Pepper

Data on the transfer efficiency of microorganisms from fomites to hands, survival on hands and transfer of microorganisms is needed for models which describe the exposure of persons in indoor environments via contaminated fomites. Such information can also be used in models to assess the success of interventions, such as, hand sanitizers, long lasting disinfectants, self-sanitizing disinfectants, etc. Data on the transfer efficiency of bacteria, viruses and spores from different surfaces is very limited and this project seeks to development more quantitative data under defined conditions which can be used in indoor exposure models. Data on the survival on hands is also needed.

This year we completed our work on the transfer efficiency of *Escherichia coli*, coliphage MS-2, and *Bacillus thuringiensis* spores on various fomite surfaces i.e. Acrylic, stainless steel, Formica, glass, ceramic tile, cotton, polyester and paper money. These were assessed under two different relative humidity conditions i.e. 20 to 30% and 45 to 65%. We also expanded our work to include the Gram positive bacterium *Staphylococcus aureus*, inclusion of vaccine strains of poliovirus types 1 (Lsc-2ab) and influenza A virus.

The transfer efficiency varied greatly among the different fomites (with hard surfaces such as stainless steel Fomica and acrylic plastics having the greatest efficiency of transfer, with fabrics and paper having the lowest. The differences in transfer efficiency among the different organisms were not large, but virus transfer was somewhat greater than the other organisms. MS-2 coliphage and poliovirus type 1 transfer efficiencies were very similar on the surfaces studied, indicating that it is a likely good surrogate for enteroviruses and perhaps other non-lipid containing viruses.
The viability of both MS-2 coliphage and *E. coli* inoculated onto fingertips did not decease significantly on fingertips after 30 minutes.

Contributor: Dr. David M. Wagner

Examination of survival rates of *Bacillus anthracis* spores from strains from the three major phylogenetic lineages to determine if they are comparable to survival rates of surrogates following exposure to different levels of pH.

Examination of survival rates of *B. anthracis* spores from strains from three major phylogenetic lineages to determine if they are comparable to survival rates of surrogates following heat exposure.

Examination of survival rates of *B. anthracis* spores from strains from three major phylogenetic lineages to determine if they are comparable to survival rates of surrogates after incubation in water.

Contributor: Dr. Mark Nicas

Completed Work

Item 1. I completed the data analysis and manuscript preparation for the droplet spray exposure study. Droplet spray refers to respiratory fluid particles that upon emission during coughing, sneezing or speaking by one person (the emitter), ballistically strike the eyes, nostrils and lips of a second person (the receptor) who is positioned face-to-face with the emitter. Such exposure requires "close contact" because the relatively large particles involved (likely those with aerodynamic diameters > 100 μm) do not travel far in air before falling out due to gravity. Being within three feet is a popular rule-of-thumb used to define close contact, but the exact distance of travel of ballistic particles of different sizes has not been investigated. Most infection control professionals and infectious disease epidemiologists believe that droplet spray exposure is an important transmission pathway for respiratory disease pathogens such as influenza virus, SARS corona virus, and pneumonic plague. We sought to investigate the potential for droplet spray exposure.

In this study, twenty subjects (10 men and 10 women) made a series of coughs at a plastic face target at distances of one, two and three feet. The face target was positioned on a wall at the same face height from the floor as that of the subject. The target was made of plastic transparency film material. The face target had separate detachable targets representing two eyes, two nostrils, and the lips. The face target itself was surrounded by background plastic sheets to collect droplet spray that did not strike the face. Prior to coughing at each distance, the subject put one mL of a saturated NaCl solution in the mouth and swirled it around with the tongue. After the series of coughs was made, the targets and background plastic sheets were taken down, chloride ion was eluted with distilled water, and the chloride ion concentration was determined with a chloride ion electrode. The total "mass" of chloride ion recovered from each target or plastic sheet was the product of the measured chloride ion concentration and the elution volume. The proportion of chloride ion mass striking the eyes, nostrils and lips was the chloride ion mass eluted from each of the respective targets divided by the total chloride ion mass recovered (from those same targets, the face, and the background plastic sheets). The proportion of chloride ion that struck a target was a surrogate for the proportion of emitted droplet spray that struck the same target.

We found great variability among the 20 subjects in the droplet spray volume recovered at each distance. For the 2-foot distance, the recovered droplet spray volumes (as measured by the chloride ion mass) are summarized in Table 1 on page 2. The total chloride ion mass recovered decreased with cough distance for most subjects, although for some subjects it increased. Table 2 on page 3 shows the percent of the total recovered chloride ion mass on the eyes, nares and lips targets at each distance for each subject. For the few subjects whose droplet spray did strike the eyes, nostrils and lips targets, the percent of the total recovered chloride ion mass on those targets was substantial, ranging from 3.3% to over 70%.

These data suggest that the ability to transmit infection by droplet spray exposure is highly variable across infected persons. Most infected persons would not transmit infection by the droplet spray route (assuming close contact with non-infected persons during coughing), but a small minority of infected persons might do so with high probability (again assuming close contact with non-infected persons during coughing). This small minority fit the concept of the "super-spreader". One limitation of our study is that all 20 subjects were healthy individuals. It is possible that persons with respiratory tract infections emit a greater volume of droplet spray, such that a greater percent of infected persons could emit ballistic particles striking the eyes, nostrils and lips of non-infected persons in close contact during coughing. A second limitation is that we did not measure droplet spray during normal speaking. It is likely that for those subjects whose ballistic particles struck eye, nostril, and lip targets during coughing, substantially fewer particles would strike those targets during normal speaking.
A manuscript presenting these data was submitted to *Journal of Occupational and Environmental Medicine*, but that journal declined to review it. The manuscript is being resubmitted to *Journal of Occupational and Environmental Hygiene*.

In Progress

Item 1. Influenza Virus Exposure via Droplet Spray – I am currently planning a droplet spray study with subjects who have influenza-like illness (ILI). The plan is to recruit students at an UC-Berkeley University Health Service (UHS) clinic who are being seen for ILI. The UHS would provide candidate students with an one-page informa-tional flier about the study and my contact information; a $50 inducement payment would be offered. The UHS would provide no health information on the subject. The candidate subjects would voluntarily contact me the same day as being seen at the UHS and arrange to visit my campus office. After explaining the study and obtaining informed consent, the name and student ID number of the subject would be recorded (to enable payment), the subject's sex, age, and date of onset of ILI symptoms would be recorded, and the subject would make a series of ten coughs at an 8″ × 11½″ plastic sheet positioned on the face of a mannequin. The subject would stand 1.5 feet from the mannequin face, and the subject and mannequin faces would be at the same height above the floor. Adhererd to the plastic sheet would be detachable plastic targets representing the eyes, nostrils and lips. After the cough series, the latter targets and the remainder of the face target would be collected, stored in a freezer, and eventually shipped to a laboratory at the National Institute for Occupational Safety and Health in Morgantown, West Virginia. A qPCR analysis would be conducted by the laboratory. Thirty to forty subjects would be recruited. Because I would not know whether a subject truly had influenza when the droplet spray samples were collected, it is likely that a good portion of the subjects would not have influenza. However, it is also likely that some portion would have influenza, and finding influenza on any eyes, nostrils and/or lips targets would be the first demonstration that influenza virus could be delivered to these targets by droplet spray. The goal is to conduct the study in December 2011 through February 2012. I have not yet submitted an application for human subjects approval because I am waiting for a letter of cooperation from the UHS. UHS staff has verbally indicated they support the study and have helped me plan the logistics.

Item 2. Field Sampling for Influenza Virus in Patient Rooms – I had been planning a study for the 2010/2011 winter season, and again for the 2011/2102 winter season, to sample for influenza virus on surfaces and in the air of rooms with patients diagnosed with influenza, and on the gloves, filter mask media and eyewear of health care workers who attend these influenza patients. The study would have been conducted at Moffitt Hospital, University of California, San Francisco, in conjunction with Robert Harrison, MD, MPH. a UC-SF faculty member in Occupational and Environmental Medicine. However, I have abandoned the project because of ongoing difficulties in securing the timely participation of collaborators at UC-SF. Despite repeated requests, Dr. Harrison did not submit the required human subjects approval application to the UC-SF institutional review board, and I never received a letter of cooperation from the UC-SF Infection Control Officer and the chairperson of the UC-SF Infectious Disease Department at UC-SF; the UC-Berkeley Committee for the Protection of Human Subjects required that I provide a letter of cooperation from UC-SF as part of the approval of my application (CPHS Protocol #2010-10-2435). I concluded that my collaborators' inability to follow through on relatively simple tasks did not portend a successful time-sensitive field study.

8. Outputs:

1. Students Supported:

Jessica Drewry, supervisor: Dr. Christopher Choi
Alex Andrade, supervisor: Dr. Christopher Choi
Yifan Liang, supervisor: Dr. Christopher Choi
Amanda Herzog, supervisor: Dr. Syed Hashsham.
Tiffany Stedtfeld, supervisor: Dr. Syed Hashsham.
Maggie Kronlein, supervisor: Dr. Syed Hashsham.
Farhan Ahmad, supervisor: Dr. Syed Hashsham.
Jerry Lopez, supervisor: Dr. Charles Gerba
Laura Y. Sifuentes, supervisor: Dr. Charles Gerba
Alejandro D. Badilla, supervisor: Dr. Charles Gerba
Ms. A. Hernandez, supervisor: Dr. Charles Gerba
Emily Kaufman, supervisor: Dr. David M. Wagner
Amber Naumann, supervisor: Dr. David M. Wagner
Christian Hochhalter, supervisor: Dr. David M. Wagner
Heather Papinchak, supervisor: Dr. Mark Nicas

2. Students Graduated:

Ryan Austin, Ph.D. , supervisor: Dr. Christopher Choi
Pedro Romero, Ph.D. , supervisor: Dr. Christopher Choi
Tulika Balagopal, M.S., supervisor: Dr. Christopher Choi

3. Publications:

Romero-Gomez, P., K. E. Lansey, C. Y. Choi, 2011, Impact of an incomplete solute mixing model on sensor network design, Journal of Hydroinformatics (in press).

Romero-Gomez P. and C. Y. Choi, 2011, Axial Dispersion Coefficients in Laminar Flows of Water Distribution Systems. ASCE Journal of Hydraulic Engineering (in press).

Syed Hashsham. Submitted manuscript to the Journal of Nanoparticle Research titled "Quantum Dots: A Review of Environmental Applications and Potential Implications for Human Health and Environment". (LU 1265)

Syed Hashsham . Submitted manuscript to the Journal Applied and Environmental Microbiology titled "Evaluation of Recovery Efficiency and Survival of Bacteriophage P22 on Fomites". (LU 1286)

Gerba, C. P. 2010. The role of fomites in transmission of pathogens in airports and on aircraft. In: Research on the Transmission of Disease in Airports and on Aircraft. Conference Proceedings 47. Transportation Research Board. National Research Council. Washington, DC.

Gerba, C. P. 2011. Microbial Risk Assessment. HPC Today. 2:6-8.

Sinclair, R. G., J. B. Rose, S. A. Hashsham, C. P. Gerba and C. N. Haas. 2011. Selection of microbial surrogates for studying and control of pathogens in the environment. Applied and Environmental Microbiology. In revision.

4. Patents:

5. Presentations:

Austin, R. G., C. Y. Choi, P. L. Gurian, T. C. Balagopal, 2010, Event-Based Microbial Risk Assessment and Response Analysis of Cryptosporidium in Municipal Water Distribution Networks, Water Distribution Systems Analysis (WDSA), Tucson, AZ.

Andrade, M. A., F. Rojano, P. Romero-Gomez, and C. Y. Choi, 2010, Integrated Water Quality Modeling of Water Distribution Systems, Water Distribution Systems Analysis (WDSA), Tucson, AZ.

Poster presentation at the 111Th General Meeting of the American Society for Microbiology, May 20-24 2011, titled "Genetic Characterization of Microorganisms on Highly Touched and Untouched Fomites" (LU 1251, Amanda Herzog)

Syed Hashsham. Biochip Analysis for Microbial Detection, On-chip PCR, Bioindicators for Pathogens. Recent Advances in Microbial Control: Society for Industrial Microbiology Meeting; Arlington, VA. 11-10-2010.

Syed Hashsham. DNA Microchips for Detection of Microorganisms in Water & Food Samples. TECAN Symposium 2010 in Salzburg, Austria: Applying Genomic Technologies. 10-08-2010.

Allen, C.A., D. Birdsell, D.L. Greenberg, E.P. Price, D.S. Sarovich, S. Wolken, A. Hurbon, P. Keim, and D.M. Wagner. Identification of *Bacillus anthracis* surrogates in experimental releases for risk assessment. Annual Meeting of the Arizona-Nevada Branch of the American Society of Microbiology, Flagstaff, Arizona, April 2011 (Talk).

Gerba, C. P. June 30, 2011. "The role of fomites in disease transmission in indoor environments". Arizona Environmental Health Association". Phoenix, AZ.

6. Organization of workshops:

7. Participation in workshops:

8. Case studies:

9. Algorithms developed:

   Christopher Choi: AZRED II – A comprehensive water quality model in pressurized water systems. Most recently, we implemented axial dispersion equations into AZRED-I, and then applied an Eulerian finite differences method (FDM) to solve the equation when applying it to pipes with laminar flow. The solute concentrations, calculated when using the equations to find the dispersion coefficients, were then used in place of the water quality values for the Lagrangian segments in the EPANET source code. The resulting computer code includes both types of mixing phenomena and serves as the basis for AZRED II, the first water quality model capable of simulating the effects of both axial dispersion and incomplete mixing.

10. Human Resource Development:

11. Funds Leveraged:
    Syed Hashsham. Two proposals listed below have been submitted to NIH. Their focus is on development of high throughput detection devices under clinical setting.

    Charles P. Gerba Two minority undergraduates student worked on this project and were supported by the University of Arizona undergraduate minority program, and the Undergraduate Research Opportunities Consortium Summer Research Institute at the University of Arizona. In addition, one minority graduate student was supported by funds supplied by the University by the Arizona.

12. Other:

9. Outcomes:
   Unit 877: The primary goal of this research is to improve our ability to understand, model, predict and therefore better control water quality in potable water distribution systems. Therefore we intend to focus on refining a valuable but outdated network water quality solver to include incomplete mixing at pipe junctions and axial dispersion of soluble constituents.

   Unit 1247: Risk assessors will have better knowledge about methods detecting respiratory and foodborne viruses.

   Unit 1249: Improve assessment of quantum dots by critically evaluating the capabilities, advantages and disadvantages which was missing in the literature.

   Unit 1254: Occurrence data for bacterial populations and presence of bacterial pathogens

   Unit 1259: Risk assessors will have better knowledge about recovery and parameters that affect recovery.

   Unit 1263: Adjustments to protocol may need to be made.

   Unit 1264: Modifications to protocol to neutralize the fomites from any chlorine residual.

   Unit 1270: First responders responsible from recovering viruses from fomites will have better knowledge

   Unit 1286: First responders will have better knowledge of the affect of certain parameters on recovery and survival of bacteriophage P22 on the fomites.

10. Integration with other projects:
    An association was created between Unit 484, authored by Rachael Jones (Project I, U of California Berkeley) and Unit 481, authored by Shamia Hoque (Project III, Drexel University)

    An association was created between Unit 481, authored by Shamia Hoque (Project III, Drexel University) and Unit 487, authored by Christopher Choi (Project I, U of Arizona)

    An association was created between Unit 579, authored by David David Greenburg (Project I, Northern Arizona U) and Unit 490, authored by Christopher Choi (Project I, U of Arizona)

    An association was created between Unit 476, authored by Mark Nicas (Project I, U of California Berkeley) and Unit 519, authored by Ian Spicknall (Project II, U of Michigan)

    An association was created between Unit 58, authored by Rosina Weber (Project V, Drexel University) and Unit 877, authored by Christopher Choi (Project I, U of Arizona)

11. Anticipated Technical Results and Developments:

CAMRA Report for Year VI (Sep 15 2010 to Sep 14 2011) for Project II

1. Project 2, Project II

2. Investigators: Joe Eisenberg, James Koopman, Ian Spicknall, Nottasorn Plipat, Bryan Mayer, Sheng Li, Jijun Zhao

3. Project Goals (from proposal, additional goals):

   The tasks for the Year 6 come out of our three main areas of research: 1) to develop a framework for analyzing environmental infection transmission systems (EITS); 2) to develop tools for model identification and model choice; and 3) to develop tools for analysis of intervention and control options.

4. Tasks for Year VI (Sep 15 2010 to Sep 14 2011):

   i. To further develop our EITS framework by developing models that account for more realistic detail of fomite mediated transmission
   ii. To apply our cumulative dose response model to tularemia dose response data
   iii. To apply our EITS model to examine dominant modes of transmission
   iv. To apply our EITS model to examine surface decontamination and hand hygiene interventions for MRSA
   v. To apply our EITS model to examining environmental intervention strategies for MSRA in hospital wards
   vi. To apply our EITS model to compare and contrast contact transmission across four pathogens: Influenza, Norovirus, MSRA, and rhinoviruses. This analysis will help inform optimal interventions

5. Research Activities
   Modeling transmission
   Research activities entered by Ian Spicknall

   Analyzing data
   Modeling epidemiologic disease
   Research activities entered by Sheng Li

   Modeling exposure
   Research activities entered by Nottasorn Plipat

   Analyzing models
   Estimating dose response model
   Research activities entered by Bryan Mayer

   Analyzing transmission
   Research activities entered by Jijun Zhao

6. Background and prior research (from learning units of the type Things I have read, those essential references you want to include; from Year II, include summary of previous years):

   Our work this year builds on our prior work in developing our EITS framework

7. Research Contributions this Year (how you advanced MRA, contributions and results from completed learning units; please list the numbers of the learning units, as follows:
   1. Comparing Contact Mediated Transmission Across Pathogens Things that are in progress LU (1230)
      Author(s): Ian Spicknall
      When Modeling transmission we wanted to find out We compare i) pathogen specific parameters which differ among norovirus, S. aureus, influenza, and rhinovirus, ii) relative shedding required to achieve specific levels of population level transmission, and iii) amenability of each pathogen to contact mediated interventions such as hand hygiene and surface decontamination.
      Experimental Design was as follows:
      We use an ordinary differential equation based environmental infection transmission system to model the contact mediated transmission routes of these pathogens, incorporating both hand hygiene and surface decontamination into this model. To parameterize the model, we characterize these pathogens in terms of their infectivity, survivability on human hands, survivability on fomite surfaces, and proportion of pathogens excreted which enter a contact transmission route beginning on the shedderï¿½??s hands.

   2. Model and Analysis of Multiple Influenza Routes (1106,1204)
      Things that are in progress LU 1106
      Author(s): Jijun Zhao
      and Things that I have completed LU 1204
      Author(s): Jijun Zhao
      When Analyzing transmission we wanted to find out Under different venue situations, which route contribute more and what cause the different results for different situations.
      Experimental Design was as follows:
      1. Establish ODE model of multiple routes including aerosol route and fomite routes. 2. Derive R0 of the whole system and of each of the routes and write into general form if possible. 3. Analyze which transmission stage is more important for different route under different venue settings: 1) shedding and contamination of route; 2) picking up and elimination of pathogens from route environment; for fomite routes, there is a third factor group, 3) human behavior after pathogens being picked up.
      Contribution:
      By distinguishing the fomite mediated routes and aerosol route, we can understand how human behaviors, population density and fomite characteristics affect the relative strength of different route, and how they affect the relative importance of stages of a transmission route. Then we can target the factors that can mostly reduce the transmission in a route to have better control.

Results:
Influenza transmission is modeled as two routes: fomite mediated transmission route, and aerosol route. Basic reproduction number (R0) formulations for these routes are derived and divided into separate stages of route contamination, transferring through environment, transferring on the target site and infection. The relative contributions of the two routes are compared by using the ratio of the R0s. Transmission via aerosol route can be higher or lower than transmission via fomite mediated route, depending on the population density, fomite size, fomite touching frequency. Transmission proportions of the same stage of the two routes are also compared to see which stage is more important for the transmission via a route.

Hand and environmental mediated transmission of MRSA (1109,1205)
Things that are in progress LU 1109
Author(s): Nottasorn Plipat
and Things that I have completed LU 1205
Author(s): Nottasorn Plipat
When Modeling transmission we wanted to find out Health care workerï¿½??s hands and hospital environments are both significant contributors to transmission of MRSA colonization. Hands are vectors of transmission introducing new acquisitions into new and clean rooms, while environments are pathogen reservoir for further acquisitions in already contaminated rooms. We would like to use the model to described hand mediated and environmental mediated transmission routes of MRSA colonization in hospital environments both clean and contaminated rooms.
Experimental Design was as follows:
1) Literature review for model parameters 2) Develop a simple conceptual model for hand and environmental mediated transmission of MRSA colonization in a hospital environment 3) Develop a corresponding individual based model for the conceptual model 4) Simulation of various scenarios 5) Simulated data analysis to describe hand mediated and environmental mediated transmission routes
Contribution:
The model demonstrated that in a setting where there is continual shedding from a source, nurses who care for an MRSA positive patient can be exposed to MRSA from both indirect contact to the contaminated room surfaces, as well as from the direct contact with the patient. This suggests that hand hygiene should be performed not only after direct contact with patients but also after indirect contact with the patientï¿½??s environment.
Results:
We used a deterministic differential equation based model to describe the MRSA exposure patterns between two patients, one colonized and the other uncolonized, residing in two separate rooms. Each room contains porous and nonporous surfaces. Nurses can transport MRSA between the rooms. MRSA transport occurred either through direct person-to-person contact or indirect contact through contaminated environment or nurses. Our main findings in the baseline scenario with no interventions were as follows: 1) nurses were contaminated more from

indirect contact with contaminated surfaces than direct contact with the MRSA positive patient; 2) contaminated nurses created more exposure for the uncolonized patient than did the contaminated room surfaces; and 3) the specific transfer efficiency of MRSA determined the role that surface had in transport. For example, due to the lower transfer efficiency, the porous surface maintained higher MRSA concentration levels than the nonporous surface in the MRSA-positive patientï¿½??s room. However, the porous surface also transferred less MRSA to nurses.

Hand and environmental mediated transmission of MRSA (1109,1208)
Things that are in progress LU 1109
Author(s): Nottasorn Plipat
and Things that I have completed LU 1208
Author(s): Nottasorn Plipat
When Modeling transmission we wanted to find out Health care workerï¿½??s hands and hospital environments are both significant contributors to transmission of MRSA colonization. Hands are vectors of transmission introducing new acquisitions into new and clean rooms, while environments are pathogen reservoir for further acquisitions in already contaminated rooms. We would like to use the model to described hand mediated and environmental mediated transmission routes of MRSA colonization in hospital environments both clean and contaminated rooms.
Experimental Design was as follows:
1) Literature review for model parameters 2) Develop a simple conceptual model for hand and environmental mediated transmission of MRSA colonization in a hospital environment 3) Develop a corresponding individual based model for the conceptual model 4) Simulation of various scenarios 5) Simulated data analysis to describe hand mediated and environmental mediated transmission routes
Contribution:
The model provided a valuable tool to assess the attributes of a decontamination intervention, taking into account continual MRSA shedding from MRSA-positive patient. The model demonstrated that the frequency of decontamination is as important as the efficacy of each decontamination event. Wiping immediately after touching a surface could be an effective ancillary decontamination method in addition to the standard daily decontamination that occurs through cleaning.
Results:
We used a deterministic differential equation based model to describe the MRSA exposure patterns as in LU # 1205. We found that the decontamination of surfaces at a minimum frequency is important in maintaining low MRSA contamination levels. Recontamination can occur quickly after decontaminating a surface.

Hand and environmental mediated transmission of MRSA (1109,1209)
Things that are in progress LU 1109
Author(s): Nottasorn Plipat
and Things that I have completed LU 1209
Author(s): Nottasorn Plipat

When Modeling transmission we wanted to find out Health care workerï¿½??s hands and hospital environments are both significant contributors to transmission of MRSA colonization. Hands are vectors of transmission introducing new acquisitions into new and clean rooms, while environments are pathogen reservoir for further acquisitions in already contaminated rooms. We would like to use the model to described hand mediated and environmental mediated transmission routes of MRSA colonization in hospital environments both clean and contaminated rooms.
Experimental Design was as follows:
1) Literature review for model parameters 2) Develop a simple conceptual model for hand and environmental mediated transmission of MRSA colonization in a hospital environment 3) Develop a corresponding individual based model for the conceptual model 4) Simulation of various scenarios 5) Simulated data analysis to describe hand mediated and environmental mediated transmission routes
Contribution:
The model highlighted the joint effects of surface decontamination and hand hygiene in reducing exposure of the MRSA-negative patient. The effectiveness of hand hygiene varied depending on surface contamination levels. Our finding indicates that MRSA infection control strategies should pay attention to both surface decontamination and hand hygiene.
Results:
We used a stochastic agent-based model to describe the MRSA exposure patterns between two patients, one colonized and the other uncolonized, residing in two separate rooms. Each room contains porous and nonporous surfaces. Nurses can transport MRSA between the rooms. MRSA transport occurred either through direct person-to-person contact or indirect contact through contaminated environment. In this model we implemented two interventions, surface decontamination and hand hygiene. We found that the effectiveness of the hand hygiene in reducing exposure dose to the patient decreased with increasing surface contamination.

Modeling influenza transmission on a college campus (511,1219)
Things that are in progress LU 511
Author(s): James Koopman
and Things that I have completed LU 1219
Author(s): Sheng Li
When Modeling transmission we wanted to find out This influenza model will help determine the relative contributions of air vs. fomite transmission in the data collected from the intervention trial as well as aiding in estimating the causal effect of handwashing and mask wearing interventions.
Experimental Design was as follows:
We want a model analysis that is capable of determining what roles the different modes of transmission play in spreading infection in University dormitories and what role transmission in dormitories plays in determining levels of infection on campus. Our model must thus capture both the physical structure in the dormitory where transmission takes place via aerosols, large droplets, or fomites and the

contact structure in the University as a whole. As our current work on route specific models of transmission is in a developmental state that does not allow for specification of the role that different routes of transmission will play under different circumstances, our campus transmission model will have to be abstract but capable of integrating model advances from our various more detailed models. Conceptualizing such a model structure is our first task.
Contribution:
Our study is one of the first to demonstrate associations between influenza morbidity and local meteorological variables and in tropical/subtropical region. Significant associations between AH and influenza morbidity, as well as between PNA and influenza epidemic patterns, were identified for the first time using influenza surveillance data. Our results advance understanding of the complex associations between weather and influenza, even though additional studies are needed to explore the mechanisms underlying this relationship.
Results:
We analyzed temporal patterns of influenza using surveillance data from a subtropical region, and considered the role of viral strain type/subtypes in identifying associations. Besides the initial annual epidemics that usually occurred between February and April, we identified a second smaller or equal-sized summer epidemic in this subtropical region based on a longer time and more reliable influenza data. Local weather variables were found statistically significantly associated with the proportion of ILI cases that tested positive for influenza virus, and the proportion of ILI diagnosis in outpatients visiting Hong Kong influenza surveillance sites. The relationships between influenza morbidity and time-lagged weather/climate variables were much stronger than non-lagged ones. The association between Absolute Humidity and influenza VPP was strongest after adjusting for other weather variables in all settings. Global climatic indicators that operate over large geographic regions were also found to be associated with observed influenza patterns.

The effects of movement patterns on flu transmission modes (857,1226)
Things that are in progress LU 857
Author(s): Sheng Li
and Things that I have completed LU 1226
Author(s): Sheng Li
When Developing models we wanted to find out 1)How venue structure and movement pattern in venues affects the relative importance of four transmission modes (frequently touched fomites, infrequently touched fomites, inspirable airborne, respirable airborne) 2) How venue structure and movement in venue structure alters the single and joint effects of four transmission modes. 3) What specific venue structure abstractions have large enough effects so that they must be considered in realistic models 4) Which specific movement abstractions have large enough effects so that they must be considered in realistic models 5) how superspreaders alter the effects of four transmission modes
Experimental Design was as follows:
1) Do literature review to summarize the important fomit type, movement patterns

and venue structure, and then conceptualize the characteristics for our theoretical agent-based model. 2) Develop an agent-based model with various human movement patterns in Java. 3) Verify the model. 4) Model parameter exploration and model simulation analysis.
Contribution:
The under-recognized temporal dynamics of different influenza transmission modes are of great public health significance, because it reminds us that it is unwise to simply exclude some interventions which specifically target less important transmission modes at the end of epidemics. This work is able to convince people to pay attention to the previously un-recognized temporal dynamics of different transmission modes over the course of influenza epidemics, and to the potentially new direction of influenza researches. This work in addition to our previous studies provide framework for understanding the influenza epidemic impacts based on not only the final morbidity, but also the temporal dynamics. These initial steps will hopefully allow us to eventually better understand transmission mode relative importance and provide better intervention suggestions on time.
Results:
To explore the dynamics of relative importance of different influenza transmission modes, an environmentally mediated agent-based mode was developed and parameterized. Human influenza transmission was modeled through four routes: fomite mediated transmission route, respiratory route, inspiratory route and droplet spray route. The analysis of model simulations has shown that the relative importance of different influenza transmission modes does vary greatly over the course of outbreaks. Specially, even in scenarios where respiratory transmission mode is ultimately dominant, non-respiratory transmission modes contribute to more to the overall transmission at the beginning of the epidemics. It takes about 10.0 days for respiratory transmissions to rise above non-respiratory transmissions. Virus particles environmental dissemination and persistence are found to be the underlying causes for these temporal dynamics of different transmission modes.

Environmental Infection Transmission System model (517,1227)
Things that are in progress LU 517
Author(s): James Koopman
and Things that I have completed LU 1227
Author(s): Sheng Li
When Developing method we wanted to find out 1. How much bias arises from different parameter estimation methods used 2. How realistic are the confidence intervals for different methods 3. Which methods provide consistent and efficient estimates
Experimental Design was as follows:
First, we will develop DC and stochastic individual-based EITS models with modest levels of intra-venue and inter-venue complexity. From the stochastic versions of these models we will generate data for parameter estimation using various methods. Then using simplified forms of the models that generated the

data, we will apply multiple methods to estimate parameters: Maximum iterative filtering, MCMC, Minimum least square. We will evaluate the performance of these methods for transmission system parameter estimation and consider modifications as indicated.
Contribution:
The results showed that the heterogeneity (superspreader) of host shedding capacity significantly affects the the chance of outbreak occurrence, the relative importance of different transmission modes, and the temporal dynamics of multiple influenza transmission modes relative importance. the results are of great public health significance, because it theoretically confirms the significant effects of superspreaders in influenza transmission, which has be studied for many other IDs such as SARS.
Results:
Superspreader, a heterogeneity of host population was implemented in an agent based influenza environmentally mediated transmission model. Super shedders refer to those who shed more virus particles than non-super shedders when they are infectious. The dynamics of different influenza transmission modes relative importance over the period of outbreaks were compared with and without superspreaders in human population. When there are superspreaders, the cumulative infection decreases for all transmission modes over the course of epidemics. The epidemics take off and reach peak level much earlier, and die out quicker than without superspreader situation. the final relative importance of different influenza transmission modes is similar to no superspreader situation, but the temporal variation of the relative importance of influenza transmission modes decreases greatly.

Comparison of the contact route of transmission (1135,1231)
Things that are in progress LU 1135
Author(s): Ian Spicknall
and Things that I have completed LU 1231
Author(s): Ian Spicknall
When Modeling transmission we wanted to find out We compare the parameter values of these agents and then examine the agent-efficacy of hand hygiene and surface decontamination.
Experimental Design was as follows:
We use an ordinary differential equation based environmental infection transmission system to explicitly model the contact mediated route of transmission for these four agents. While these agents have characteristics that are unique to each of them (infectivity, inactivation rates, and proportion of material shed which goes directtly to the hands of the shedder), there are many other parameters which have shared values (touching rates, touching patterns, host density, etc.). We compare parameter values of these agents, and then examine how these agents (as defined by their parameter values) are affected differently by hand hygine and surface decontamination.
Contribution:
If empirical estimates from the literature are accurate, it is likely that contact

mediated interventions such as hand hygiene and surface decontamination provide a much smaller benefit against influenza and rhinovirus transmission, compared to S. aureus and norovirus transmission. These latter agents are much more easily transmissible, in part because of their greater survivability in the environment on fomites and human hands.
Results:
Norovirus has the highest infectivity of these pathogens studied. S. aureus and norovirus both survive much longer in the environment on fomites and hands of people compared to influenza and rhinovirus. Norovirus requires the lowest levels of shedding over the course of an infection to cause 50% final fraction infected in the population. S. aureus requires 14 times more pathogen excretion, while influenza and rhinovirus requires greater than 3000 times more excretion than norovirus, when touching was performed randomly in the venue. When we examined how often a hand hygiene or surface decontamination intervention must be applied to reduce infection substantially, we observed that for hand hygiene, norovirus was most amenable, followed by S. aureus and rhinovirus. Influenza does not respond to hand hygiene substantially, as even with it being applied once every 10 minutes to all hands, only 20% intervention efficacy was conveyed; this is likely due to influenzaï¿½??s much higher inactivation rate on hands compared to these other pathogens. For surface decontamination, S. aureus was the most amenable, as cleaning once every 3 days conveyed nearly 100% efficacy. Norovirus was next most amenable, as cleaning once each day conveyed nearly 100% efficacy. Influenza and rhinovirus followed, but required a high frequency of venue cleaning to produce a large intervention effect.

3. impact of waning immunity on polio transmission systems (1199,992)
   Things that are in progress unit Number 1199
   Author(s): Bryan Mayer
   and Things that I have progress unit Number992
   Author(s): Bryan Mayer
   Initially Analyzing models we wanted to find out Explore the interaction between the environment and vaccination to evaluate the role of environmental interventions for pathogens with vaccines (currently or in development).
   The original Experimental Design was as follows:
   Explore the interaction between the environment and vaccination to evaluate the role of environmental interventions for pathogens with vaccines (currently or in development).
   We are currently trying to find out The underlying framework for the success of polio eradication lies in coverage levels, transmission of oral polio vaccine, sanitation levels (R0), and the level at which immunity wanes.
   The current Experimental Design is as follows:
   A compartmental model was developed to explore vaccination implementation in conjunction with waning immunity to explore dynamics. We explored settings for both countries with successful polio elimination and countries with difficulty reaching elimination.

4. Summary of Preliminary Tularemia Dose-Response Experiments (820,1201)
   Things that are in progress unit Number 1201
   Author(s): Bryan Mayer
   and Things that I have completed unit Number 820
   Author(s): Bryan Mayer
   Once we learned:
   The need for more specific data concerning time-dependent exposure events. Specifically, time to infection and ranges for host clearance for specific pathogens. Furthermore, controlled experiments will be required to understand if dose timing and dose order are important for risk estimation.
   This result led us to the following research question Estimating dose response model we wanted to find out If the risk of tularemia infection is impacted by different dose-timings.
   The current Experimental Design is as follows:
   Using our previous developed model for estimating time-dependent dose-response data, we analyzed the results of an animal study of tularemia in mice that utilized time-dependent dosing. We also explored the results using traditional dose-response methods in conjunction with basic statistical analysis.

8. Outputs:
   1. Students Supported:

      Bryan Mayer

   2. Students Graduated:

      Ian Spicknal (defended PhD 11/10)
      Sheng Li (defended PhD 2/11)
      Nottasorn Pilat (defended PhD 8/11)

   3. Publications:
   4. Patents:
   5. Presentations:
   6. Organization of workshops:
   7. Participation in workshops:
   8. Case studies:
   9. Algorithms developed:
   10. Human Resource Development:
   11. Funds Leveraged (additional funding. resources for free):
   12. Other:

9. Outcomes (how your contributions can be used to better society):

Unit 1199: Efforts in improving sanitation may drastically reduce the vaccine coverage needs

Unit 1201: Time-dependent risk calculations will vary from calculations from time-independent models

Unit 1204: 1. Fomite route is much more (tens to hundreds times) contaminated than the aerosol route for the environmental setting that has a large total fomite area. For an environmental setting that has a total small fomite area, fomite route is more contaminated than the aerosol route, however their contamination levels are in a same scale. 2. Conditions where transmissions via fomites could exceed transmissions via aerosol route are: when the total fomite size is large, and the fomite is not rarely touched; if the fomite is large and also rarely touched, the population density has to be low; when the environmental setting has small fomite size, the fomite is highly touched and the ventilation rate is high. 3. Using of masks in Infected individuals can reduce the contamination level of fomite route, and reduce the relative importance of fomite route. 4. Small size fomite can transfer more proportion of virus than aerosol route. Frequently touched fomite can also transfer more proportion of virus than aerosol route. However most virus picked up to hands die on hands. 5. The proportion of virus that can transfer through air is higher than the proportion of virus that can transfer through fomites and then through hands. 6. Fomite route of a environmental setting with large fomites can have higher influenza transmission than aerosol route because the contamination of fomites is much higher than aerosol.

Unit 1205: As described above in summary.

Unit 1208: The model allowed for the decontamination method assessment, which takes into account the continual nature of MRSA shedding process from MRSA-positive patient. By doing so, the model demonstrated that the frequency of the decontamination event is as important as the efficacy of each decontamination. Thus, wiping could be an ancillary decontamination method in addition to the current daily decontamination regime.

Unit 1209: As described above in summary.

Unit 1219: described as above.

Unit 1226: As described above.

Unit 1227: The super shedders mitigate temporal dynamics of the relative importance of different influenza transmission modes over the course of outbreaks, although the final relative importance of different transmission modes barely changes. The changes in temporal dynamics of different transmission

modes caused by superspreader originate from the increased viral particles at the beginning of epidemics.

10. Integration with other projects (association between units in different projects):
    An association was created between Unit 372, authored by Sheng Li (Project II, U of Michigan) and Unit 426, authored by Scott McLennan (Project IV, Michigan State U)
    An association was created between Unit 476, authored by Mark Nicas (Project I, U of California Berkeley) and Unit 519, authored by Ian Spicknall (Project II, U of Michigan)
    An association was created between Unit 748, authored by Ian Spicknall (Project II, U of Michigan) and Unit 762, authored by Patrick Gurian (Project IV, Drexel University)

11. Tasks for Next Year: VII (Sep 15 2011 to Sep 14 2012)

i. Our tasks for next year are to publish six projects that we have been working on this past year:
ii. We plan to publish our work on polio in two manuscripts with an emphasis on how improving sanitation can lessen the necessary vaccine coverage for eradication. (Working title for manuscript 1: "Successes and failures in polio eradication campaigns: a transmission systems analysis")
iii. We plan to publish our work on MRSA in two manuscripts. The first manuscript will be a detailed exposure analysis model that examines the role of the environment in exposure. The second manuscript will examine the joint effects of hand hygiene and decontamination. Specifically, we will highlight our finding that the effectiveness of the hand hygiene in reducing exposure dose to the patient decreased with increasing surface contamination
iv. We plan to publish our work comparing and contrasting optimal intervention strategies for four pathogens that exploit the environment in different ways. The pathogens are influenza, norovirus, MSRA, and rhinoviruses.
v. We are about to submit a manuscript entitled "Model Analysis of Fomite Mediated Influenza Transmission" that advances our theory of EITS.

Anticipated Technical Results and Developments (examples of potential learning units for next year, within possible also include potential outcomes):

CAMRA Report for Year VI (Sep 15 2010 to Sep 14 2011) for Project III

1. Project 3, Project III

2. Investigators: Chuck Haas, Mark Weir, Tim Bartrand, Carole Bolin, Bidya Prasad, Sushil Tamrakar, Sharon Nappier , Yin Huang , Toru Watanabe, Kerry Hamilton, Shamia Hoque, Sondra Teske

3. Project Goals (from proposal, additional goals):

4. Tasks for Year VI (Sep 15 2010 to Sep 14 2011):

5. Research Activities
   Developing dose response model
   Research activities entered by Sushil Tamrakar

   Developing dose response model
   Research activities entered by Sondra Teske

   Validating data analysis
   Developing models
   Research activities entered by Bidya Prasad

6. Background and prior research (from learning units of the type Things I have read, those essential references you want to include; from Year II, include summary of previous years):

   Things I have read Learning Unit number 1212
   The primary goal was to validate Thayyer-Madabusi's Listeria dose-response work from his MS thesis, where he used Excel calculations with class R code.
   Thayyar-Madabusi, A. (1998). A Quantitative Risk Assessment Model for Listeria monocytogenes and Escherichia coli O157:H7. Environmental Science. Philadelphia, Drexel University. MS: 172.
   Things I have read Learning Unit number 1214
   Incorporate time dose response with an incubation period model, using exponential and beta-Poisson TDR models which includes bacterial growth rate and apply them to infectivity and incubation distribution.
   Gupta, M. (1999). Development and Use of a Dynamic Disease Propagation Model For Assessing Risk from Common Source Epidemics. Environmental Science, Engineering and Policy. Philadelphia, Drexel University.
   Things I have read units entered by Bidya Prasad

7. Research Contributions this Year (how you advanced MRA, contributions and results from completed learning units; please list the numbers of the learning units, as follows:
   1. Dose Response Models incorporating Aerosol Size Dependency Things that are in progress LU (1188)
      Author(s): Sondra Teske

When Developing dose response model we wanted to find out How increasing aerosol particle diameter size affects dosage requirements for each disease process
Experimental Design was as follows:
create individual dose response models for each experimental infection studies' aerosol diameter size and try to model the rates of change of the model parameters with increase in diameter

Leptospirosis dose response models Things that are in progress LU (1190)
Author(s): Sondra Teske
When Developing dose response model we wanted to find out Whether experimental infection studies with different serogroups and serovars (that are differentiated only through surface proteins) can be represented by common dose response models.
Experimental Design was as follows:
Find as many experimental infection studies and create dose response models for them and see if there is possible pooling between datasets that can improve our understanding of the disease process and pathology.

2. Dose Response Models incorporating Aerosol Size Dependency (1188,1189)
Things that are in progress LU 1188
Author(s): Sondra Teske
and Things that I have completed LU 1189
Author(s): Sondra Teske
When Developing dose response model we wanted to find out How increasing aerosol particle diameter size affects dosage requirements for each disease process
Experimental Design was as follows:
create individual dose response models for each experimental infection studies' aerosol diameter size and try to model the rates of change of the model parameters with increase in diameter
Contribution:
Predictive dose response models were created that both had power function modified rate parameters, but were unique for each bacterial study.
Results:
Developed 2 aerosol diameter dependent dose response models for F tularensis and B anthracis with bioaerosol diameters ranging between 0.83-24Î¼m. F. tularensis was best fit by an exponential model with k modifed by a power function; B anthracis was best fit by a beta-Poisson model with N50 modified by a second order power function.

Leptospirosis dose response models (1190,1193)
Things that are in progress LU 1190
Author(s): Sondra Teske
and Things that I have completed LU 1193
Author(s): Sondra Teske
When Developing dose response model we wanted to find out Whether experimental infection studies with different serogroups and serovars (that are

differentiated only through surface proteins) can be represented by common dose response models.
Experimental Design was as follows:
Find as many experimental infection studies and create dose response models for them and see if there is possible pooling between datasets that can improve our understanding of the disease process and pathology.
Contribution:
There were very few datasets that could be pooled that were from different serogroups, serovars or strains reflecting the diversity of Leptospira's genetic diversity and ability to transfer pathogenic virulence factors.
Results:
Created dose response models for 22 datasets and attempted pooling between them

Dose-response model of Rickettsial diseases and other biological (1129,1196)
Things that are in progress LU 1129
Author(s): Sushil Tamrakar
and Things that I have completed LU 1196
Author(s): Sushil Tamrakar
When Analyzing dose response model we wanted to find out Multi-routes dose-response model, interspecies susceptibility
Experimental Design was as follows:
1. explore the data 2. test for trend 3. dose-response model using MLE 4. Analyzing
Contribution:
Multi-routes dose-response models
Results:
The disseration contains dose-response models of rickettsia species and other biological agents of concern including Lassa virus fever, Q fever, Meliodoisis. It also contains development of multi-routes dose response model and interspeciese analysis of rickettsiae.

8. Outputs:
    1. Students Supported:
    2. Students Graduated:
    3. Publications:
       Dose-Response Model for Rocky Mountain Spotted Fever (RMSF) for Human
       The paper has been published in Risk Analysis(March 2011, early online publication)
       Accomplishments bySushil Tamrakar
    4. Patents:
    5. Presentations:
    6. Organization of workshops:
    7. Participation in workshops:
    8. Case studies:
    9. Algorithms developed:

10. Human Resource Development:
11. Funds Leveraged (additional funding. resources for free):
12. Dissertation:
    Dose-Response Models of Rickettsiae and Other Biological Agents of Concern
    The dissertation was successfully defended.
    Accomplishments bySushil Tamrakar

9. Outcomes (how your contributions can be used to better society):

    Unit 1188: Improve current bioaerosol dose response modeling

    Unit 1189: Paper submitted to journal for review and possible publication. This may advance bioaerosol dose response modeling

    Unit 1190: Improve knowledge of how diversity of identified classes of Leptospira present in a mechanistic dose response framework

    Unit 1193: Develop several dose response models that were unavailable before

    Unit 1196: various dose-response modeld

    Unit 1212: Validate his work while I was learning to use R.

    Unit 1214: Expected results are a new dose-response model that takes into account the infectivity and incubation of an organism in the established TDR models.

10. Integration with other projects (association between units in different projects):

    An association was created between Unit 609, authored by Mark Weir (Project III, Drexel University) and Unit 469, authored by Patrick Gurian (Project IV, Drexel University)
    An association was created between Unit 484, authored by Rachael Jones (Project I, U of California Berkeley) and Unit 481, authored by Shamia Hoque (Project III, Drexel University)
    An association was created between Unit 481, authored by Shamia Hoque (Project III, Drexel University) and Unit 487, authored by Christopher Choi (Project I, U of Arizona)
    An association was created between Unit 609, authored by Mark Weir (Project III, Drexel University) and Unit 530, authored by Patrick Gurian (Project IV, Drexel University)
    An association was created between Unit 521, authored by Mark Weir (Project III, Drexel University) and Unit 540, authored by Jade Mitchell-Blackwood (Project IV, Drexel University)
    An association was created between Unit 609, authored by Mark Weir (Project III, Drexel University) and Unit 540, authored by Jade Mitchell-Blackwood (Project IV, Drexel University)

An association was created between Unit 352, authored by Scott McLennan (Project V, Michigan State U) and Unit 669, authored by Mark Weir (Project III, Drexel University)

11. Tasks for Next Year: VII (Sep 15 2011 to Sep 14 2012)

    Anticipated Technical Results and Developments (examples of potential learning units for next year, within possible also include potential outcomes):

CAMRA Report for Year VI (September 15, 2010 to September 14, 2011) for Project IV

1. Project IV

2. Investigators: Patrick Gurian, Mark H. Weir, Elizabeth Casman, Jade Mitchell-Blackwood, Scott McLennan , Tao Hong, Nicholas Ward, David Durham

3. Project Goals:
   Use a scenario-based approach to identify key decision points and uncertainties in bioterrorism risk management plans.

   Develop statistical descriptions of uncertainty in model parameters

   Identify strategies to reduce uncertainty and manage bioterrorism risk.

4. Tasks for Year IV (September 15, 2008 to September 14, 2009):

   Dr Elizabeth Casman's Laboratory (Carnegie Mellon)

   Understand how the public's perception of bioterrorism or pandemic risks affects their behavior and abilities to effectively manage their personal risks

   Devise a scenario-based method for identifying content for risk communications in epidemic or bioterrorism settings.

   Dr. Patrick L. Gurian's Laboratory (Drexel)

   Interpreting environmental sampling

   a) Assessment of sampling and modeling strategies to characterize a release.

   This study addresses the question of whether the size fraction can be identified based on simple aggregate concentration measurements, such as could reasonably be made after an actual release. A variety of alternative model formulations and sampling schemes are considered in order to assess how much detail on the size distribution of the release can realistically be identified from surface sampling results. A new framework for evaluating different sampling approaches was developed during this project period in which Monte Carlo simulations are used to simulate the effects of measurement errors in estimates or risk. Result suggest that three size particle models

can give reasonably accurate measures of risk while single size fraction models may over or under estimate risk by orders of magnitude. A draft paper has been prepared.

b) Sampling results from the Hart Senate Office Building will be used to update fate and transport model parameters for *B. anthracis* spores.

In this task, the Bayesian Monte Carlo (BMC) method was used to update a published fate and transport model of pathogens' indoor air movement method. Uncertainty distributions for model parameters (e.g., turbulence intensity, particle density, settling velocity, resuspension rate, distribution of particle size, risk to exposed people, etc.) were updated through the BMC method (using Markov Chain Monte Carlo sampling) by comparing model predictions with measurements from a study of the secondary aerosolization of *B. anthracis* spores from one of the 2001 anthrax letter attacks. Results indicate that surface sampling can inform order of magnitude estimates of risk. A paper describing results is now in draft form.

c) Recovery efficiency for different surface sampling methods (e.g., wipe, swap, and vacuum sock) will be estimated based on data collected by the Idaho National Laboratory is submitted for publication.

This work improved the understanding of accuracy of surface sampling by estimating recoveries for spores from field data provided by the Idaho National Laboratory under different sampling conditions. A paper has been submitted for publication and is now being revised to address reviewer comments.

d) A paper linking environmental concentration with risk for Category A pathogens is submitted for publication.

This work inherited the method from a previous publication and applied it to five Category A pathogens (*Bacillus anthracis, Yersinia pestis, Francisella tularensis, Variola major* and Lassa) to develop quantitative guidelines for how environmental pathogen concentrations may be related to human health risk. It integrated dose response information provided by Project III and environmental persistence data provided by Project I. A journal paper on this topic is under review.

1. Hierarchical Modeling of Dose Response Variability

a) **The hierarchical approach developed in previous project periods for *B. anthracis* will be applied to *F. tularensis* and *Cryptosporidium*.**

This research has also been completed and documented in Jade Mitchell-Blackwood's dissertation. A presentation based on this work was made at the 2010 Society for Risk Analysis Annual Meeting.

2. Decision Thresholds for Microbial Risk

a) A decision model identifying response thresholds for *B. anthracis* exposure will be developed.

This work used benefit-cost assessment to identify risk thresholds for three different response options: antibiotic prophylaxis, vaccination, and environmental decontamination. A journal paper has been published describing the results:

Mitchell-Blackwood, J., P.L. Gurian, C. O'Donnell, "Finding Risk-based Switchover Points for Response Decisions for Environmental Exposure to Bacillus anthracis", Human and *Ecological Risk Assessment*, 2011. 17(2): p. 489-509.

b) A decision model for environmental detection of *B. anthracis* will be refined and the results submitted for publication.

This work developed a model to estimate the value of an environmental detection system for bioterrorism agents. The following paper is in draft form and ready to submit to a journal:

Madsen, J.M., and P.L. Gurian. "Valuation of Environmental Detection of a Bacillus anthracis Release"

c) A decision model for responding to *Cryptosporidium* contamination of a public water supply will be refined and the results submitted for publication.

This paper has been revised, including a review by members of Project III and Project I. We plan to submit the revised paper to a journal by the end of November.

d) A decision-tree model balancing different options after a release of *B. anthracis* spores is under development.

This study will extend the previous work (described in a above) by including evacuation as an option as well as different combinations of response actions. A decision model has been developed and a paper is being drafted.

5. Research Activities:

Researcher Name	Research Activity
Patrick L. Gurian	Supervise graduate student research Review and revise preliminary research products
Tao Hong	Modeling fate and transport
Kyle Griffith	Analyzing data from Idaho National Laboratories field test to estimate microbial recoveries obtained from different surfaces and sampling methods.
Heather Galada	Assisting dose response analysis

	Performing background research on existing response knowledge and gaps
Emily Jackson	Anthrax scenario and decision modeling
Michael Hamilton	Developing a decision-tree model balancing different options after an anthrax attack.

6. Background and prior research:

   The Drexel component of Project IV has three main thrusts, 1) fate and transport modeling to link measurement results with human health risk, 2) Bayesian hierarchical dose response modeling, and 3) decision modeling. Research in prior years has developed models in each of the three areas. The project is now in a phase of documenting and seeking to publish results.

7. Research Contributions this Year:

   1. Balancing different options after an anthrax attack Things that are in progress LU (1279)
      Author(s): Michael Hamilton, Tao Hong, Elizabeth Casman, and Patrick Gurian
      When Comparing response scenario we wanted to find out Recent papers have considered appropriate responses to a wide-area terrorist release of *Bacillus anthracis* in a major urban area, including several published in Biosecurity and Bioterrorism. A research gap noted by many of these papers is the need for a quantitative risk assessment to help inform response-related decisions following such a release in order to optimize available resources and minimize undesirable outcomes. A fundamental question that must be answered is: What is the proper response to an attack to allow re-occupancy of the affected area?
      Experimental Design was as follows:
      This study seeks to present a benefit-cost analysis of possible responses -- including but not limited to vaccination, decontamination, and evacuation -- and makes recommendations based on the level of risk of exposure. Specifically, by utilizing a decision tree and associated costs, the switchover points between different response options are calculated (in terms of risk) to provide policy-makers with a tool to facilitate effective decision making.

   2. An Analysis of Microbial Spore Recovery Methods (1031,1273)
      Things that are in progress LU 1031
      Author(s): Kyle Griffith, Tao Hong, Igor Burstyn, Dino Mattorano, and Patrick Gurian
      and Things that I have completed LU 1273
      Author(s): Kyle Griffith, Tao Hong, Igor Burstyn, Dino Mattorano, and Patrick Gurian
      Experimental Design was as follows:

Potential health risks associated with biological agent surface contamination indoors have created a need for improved understanding of surface sampling in contamination assessment and resolution. In this paper, microbial spore recovery data from two separate large-scale (sample sizes are 1675 and 916 respectively) field dissemination experiments are examined to identify potential relationships between final spore concentrations and pre-defined parameters related to sampling methodology. The efficiency of various collection methods is analyzed for possible causality in microbial spore recovery; while controlling for the effect of different test events, building rooms, object types, and surface types.
Results:
The use of the wipe collection method on non-porous surfaces resulted in the highest recoveries: fractional recovery (FR) = 50.4% (95% CI = 31.8% - 79.7%). Lower recoveries were observed for other methods: for RMC FR was 28.7% (95% CI = 16.2% - 51.0%), for swab (non-porous) FR was 2.5% (95% CI = 1.1% - 6.0%), for vacuum sock FR was 1.0% (95% CI = 0.6% - 1.5%). A limitation of this work is an unbalanced study design among collection methods, but it is counter-weighed by the large sample size and use of data from a realistic office building test environment.

8. Outputs:
    1. Students Supported:

    Primary support from CAMRA:
    Tao Hong, supervisor: Patrick Gurian

    Students contributing to CAMRA but with primary support from outside CAMRA
    Michael Hamilton, M.S. student, supervisor: Patrick Gurian
    Emily Jackson, M.S. student, supervisor: Patrick Gurian
    Heather Galada, supervisor: Patrick Gurian
    Kyle Griffith, supervisor: Patrick Gurian

    2. Students Graduated:
    Heather Galada received her master degree in the summer of 2011, supervisor: Patrick Gurian

    Kyle Griffith received his M.S. and finished a Master thesis entitled "Comparison of Methods for Quantification of Surface Contamination with Microbial Spores in an Office Building" in the Summer of 2011, supervisor: Patrick Gurian

    David Durham Ph.D., supervisor: Elizabeth Casman

3. Publications:

Published:

Mitchell-Blackwood, J., P.L. Gurian, and C. O'Donnell, "Finding Risk-Based Switchover Points for Response Decisions for Environmental Exposure to Bacillus anthracis". Human and Ecological Risk Assessment, 2011. 17(2): p. 489-509.

Hong, T., P.L. Gurian, N.F. Dudley Ward. 2010. "Setting Risk-Informed Environmental Standards for Bacillus Anthracis Spores," Risk Analysis, 30(10):1602-1622.

Solon, I., P.L. Gurian, H. Perez. "The Extraction of a Bacillus anthracis Surrogate from Pleated HVAC Filter Samples," Indoor and Built Environment (in press).

Bruine de Bruin, W., Parker, A.M., & Maurer, J. (2011). Measuring perceived invulnerability to H1N1 (swine) flu risks. Journal of Risk and Uncertainty, 42, 145-159.

Submitted:

Tao Hong, P.L. Gurian, Y. Huang, and C.N. Haas, "Prioritizing Risks and Uncertainties from Intentional Release of Selected Category A Pathogens" submitted to PLoS ONE.

Kyle C. Griffith, Tao Hong, Igor Burstyn, and Dino Mattorano, "Comparison of Methods for Quantification of Surface Contamination with Microbial Spores in an Office Building" submitted to Applied and Environmental Microbiology

Bruine de Bruin, W. & Carman, K.C. (submitted). The effect of response format on reported risk perceptions. Target journal: Journal of Risk and Uncertainty.

In preparation:

Michael Hamilton, T. Hong, E. Casman, and P.L. Gurian "Balancing different options after an anthrax attack". Target Journal: Biosecurity and Bioterrorism.

Bruine de Bruin, W., Downs, J.S., & Casman, E. (in preparation). Decisions about flu prevention. Target journal: Risk Analysis.

Two papers are in preparation on model calibration and identifiability by Tao Hong, which will form the remainder of his doctoral dissertation. One paper on benefit-cost analysis boil water order for Cryptosporidium is in preparation. One paper based on Heather Galada's paper on first responder training needs to address bioterrorism incidents is in draft form.

Citations:

1. The following paper, which was jointly authored by Drexel Project III and IV and published during the previous project reporting period:

   Huang, Y., T. Hong, T. Bartrand, P.L. Gurian, C.N. Haas, R. Liu and S. Tamrakar. 2010. "How Sensitive is Safe? Risk-based Targets for Ambient Monitoring of Pathogens," IEEE Sensors Journal, 10(3):668-673.

   Has been cited by the following two papers:

   Mitchell-Blackwood, J., P.L. Gurian, and C. O'Donnell, "Finding Risk-Based Switchover Points for Response Decisions for Environmental Exposure to Bacillus anthracis". Human and Ecological Risk Assessment, 2011. 17(2): p. 489-509.

   Huang Yin; Haas Charles N. 2011. "Quantification of the Relationship between Bacterial Kinetics and Host Response for Monkeys Exposed to Aerosolized Francisella tularensis"

   APPLIED AND ENVIRONMENTAL MICROBIOLOGY, 77 (2):485-490.

2. E. Casman and B. Fischhoff, (2008) "Risk Communication Planning for the Aftermath of a Plague Bioattack," *Risk Analysis*, 28(5):1327-1342. – cited 3 times

   Cited by:

   1. Title: Scenario-based multiple criteria analysis for infrastructure policy impacts and planning
   Author(s): Schroeder Matthew J.; Lambert James H.
   Source: JOURNAL OF RISK RESEARCH Volume: 14 Issue: 2 Pages: 191-214 DOI: 10.1080/13669877.2010.515314 Published: 2011

   2. Title: Biosafety Level 2 Model of Pneumonic Plague and Protection Studies with F1 and Psa
   Author(s): Galvan Estela M.; Nair Manoj Kumar Mohan; Chen Huaiqing; et al.
   Source: INFECTION AND IMMUNITY Volume: 78 Issue: 8 Pages: 3443-3453 DOI: 10.1128/IAI.00382-10 Published: AUG 2010

   3. Title: REPORT OF THE INTERNATIONAL CONFERENCE ON RISK COMMUNICATION STRATEGIES FOR BSL-4 LABORATORIES, TOKYO, OCTOBER 3-5, 2007
   Author(s): Dickmann Petra; Keith Kelly; Comer Chris; et al.
   Source: BIOSECURITY AND BIOTERRORISM-BIODEFENSE STRATEGY PRACTICE AND SCIENCE Volume: 7 Issue: 2 Pages: 227-233 DOI: 10.1089/bsp.2009.0023 Published: JUN 2009

4. Patents:

5. Presentations:
   Tao Hong and P.L. Gurian, "A Bayesian Monte Carlo approach to model calibration for weaponized B. anthracis fate and transport", in Society for Risk Analysis 2010 Annual Meeting. Salt Lake City, UT, December 2010.

   Mitchell-Blackwood, J. and P.L. Gurian, "Bayesian model comparison of dose-response models for biological agents," Society for Risk Analysis 2010 Annual Meeting, Salt Lake City, UT, December 2010.

   Tao Hong and Patrick Gurian. "A Bayesian Approach to Model Calibration for Weaponized B. Anthracis Risk Assessment", in U.S. Department of Homeland Security University Network Summit and Student Day, Washington DC, March, 2011.

   Gurian, P.L. and T. Hong, "Uncertainty in Quantitative Microbial Risk Assessment Models", invited seminar Villanova University Department of Civil and Environmental Engineering, January 21, 2011.

6. Organization of workshops:

   Heather Galada, Charles Gerba, Alrica Joe, Arun Kumar, Elia Marquez, Mira S. Olson, Ian Pepper, Evan Richter, Jingjie Teng, and Patrick L. Gurian. 2011. "Teaching Quantitative Microbial Risk Assessment in Environmental Engineering & Science," Association of Environmental Engineering and Science Professors, University of South Florida, Sunday July 10, 2011.

7. Participation in workshops:

8. Case studies:

9. Algorithms developed:

   Matlab code was developed to estimate the release quantity of *B. anthracis* spores based on surface sampling results.

10. Human Resource Development:

    Five students worked in conjunction with this project (1 doctoral and 4 masters), supported by CAMRA funds and/or fellowship funds (see "student supported" and "students graduated" above for details).

11. Funds Leveraged:

    Two masters students (Galada and Griffith) worked on CAMRA with support from a DHS-sponsored fellowship programs. Additional support for students was obtained from teaching assistantships provided by Drexel University.

9. Outcomes:

10. Integration with other projects :

    An association was created between Unit 609, authored by Mark Weir (Project III, Drexel University) and Unit 469, authored by Patrick Gurian (Project IV, Drexel University)
    An association was created between Unit 469, authored by Patrick Gurian (Project IV, Drexel University) and Unit 478, authored by Mark Nicas (Project I, U of California Berkeley)
    An association was created between Unit 609, authored by Mark Weir (Project III, Drexel University) and Unit 530, authored by Patrick Gurian (Project IV, Drexel University)
    An association was created between Unit 609, authored by Mark Weir (Project III, Drexel University) and Unit 540, authored by Jade Mitchell-Blackwood (Project IV, Drexel University)
    An association was created between Unit 521, authored by Mark Weir (Project III, Drexel University) and Unit 540, authored by Jade Mitchell-Blackwood (Project IV, Drexel University)
    An association was created between Unit 748, authored by Ian Spicknall (Project II, U of Michigan) and Unit 762, authored by Patrick Gurian (Project IV, Drexel University)

11. Anticipated Technical Results and Developments:

CAMRA Report for Year VI (September 15, 2010 to September 14, 2011) for Project V

1. Project V

2. Investigators: Testuser9 first name Testuser9 last name, Rosina Weber, Test Ser, Yuan An, Zunyan Xiong, Mark H. Weir, S. Devin McLennan, XuNing Tang, Sidath Gunawardena, Marcia Morelli, Jay Johnson, Thomas Burke, Stephen Morse, Rebecca Parkin, Suresh Pillai, Desiree Linson

3. Project Goals (from proposal, additional goals):

   It is the overall objective of this project to investigate and implement effective and efficient methods to enhance the understanding of microbial risk assessment (MRA) as a body of knowledge. These are the objectives, approaches, and expected results from this project:

   1. Build and maintain online collaborative repository.

   2. Build and maintain an open repository, the Camra Wiki.

4. Tasks for Year IV (September 15, 2008 to September 14, 2009):

Improve and maintain repositories while supporting CAMRA users.

5. Research Activities:
   Investigating further uses of knowledge in CAMRA KR

6. Background and prior research:

7. Research Contributions this Year:
   LU 1293

8. Outputs:
   1. Students Supported:
   2. Students Graduated:
   3. Publications:
      REPRESENTING SCIENTIFIC KNOWLEDGE
      Rosina O. Weber and Sidath Gunawardena. 2011. REPRESENTING SCIENTIFIC KNOWLEDGE. Cognition and Exploratory Learning in Digital Age (CELDA 2011) [accepted paper]

      BLUEPRINTS FOR SUCCESS
      Sidath Gunawardena and Rosina O. Weber. 2011. BLUEPRINTS FOR SUCCESS: Recommending Characteristics of Multidisciplinary Collaboration Teams. 4th International Conference on Agents and Artificial Intelligence. [accepted paper]

   4. Patents:

   5. Presentations:
      Helping Scientists Collaborate
      This presentation was given to an audience of staff researchers at DFKI, Kaiserslautern, Germany. DFKI stands for German Research Center for Artificial Intelligence
      Accomplishments by Rosina Weber

   6. Organization of workshops:

   7. Participation of workshops:

   8. Case studies:

   9. Algorithms Development:

   10. Human Resource Development:

   11. Funds Leveraged:

   12. Other (consulting, interviews, etc.):

9. Outcomes:

10. Integration with other projects:

11. Anticipated Technical Results and Developments:

Citations of your CAMRA published work:
Citation of CAMRA-funded paper:
Citations of Publications
Camra funded papers produced by PROJECT V have been cited 26 times (excluding self citations). Attachment contains table of citations

Final Tasks for Next Year:

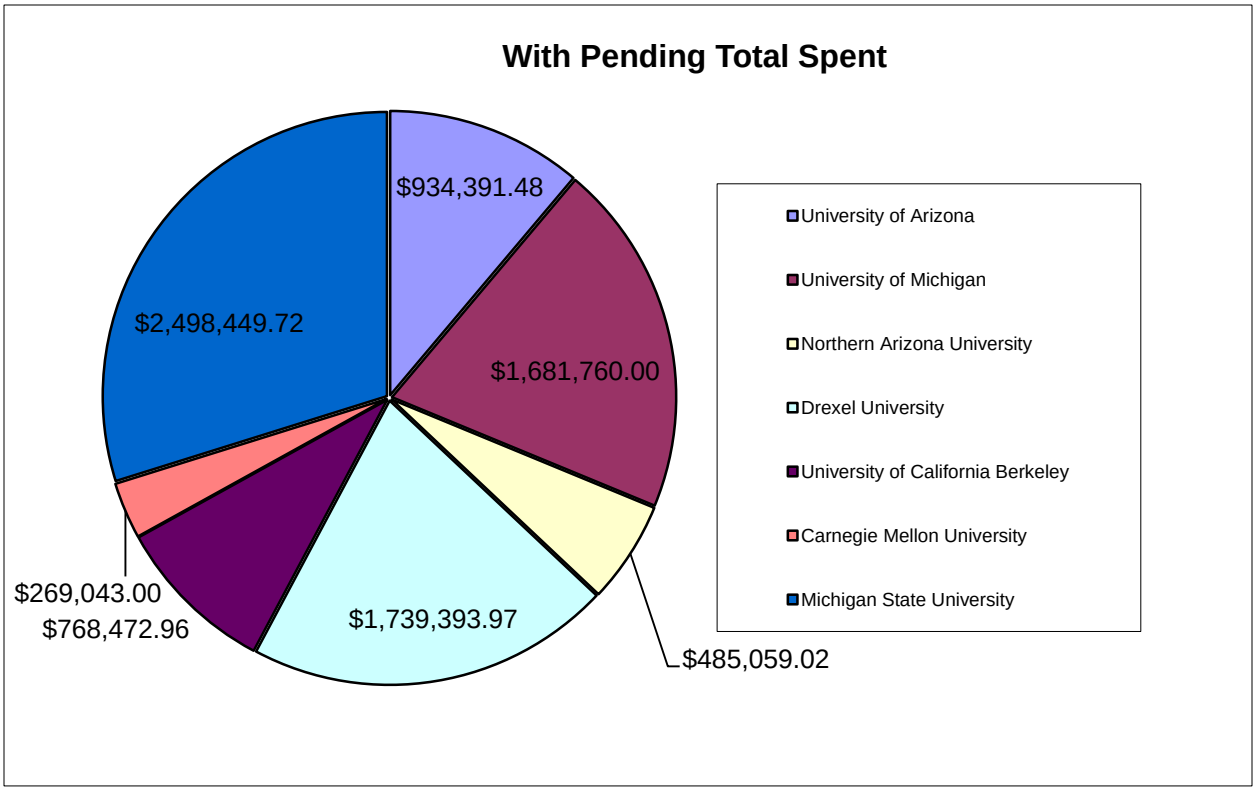
1. **Devise a maintenance plan for both the CAMRA KR and the CAMRA Wiki**
2. **Revise and fix bugs in CAMRA KR**
3. **Create a shell from the CAMRA KR to be offered to other collaborative projects**
4. **Continue to support repositories while supporting CAMRA users.**

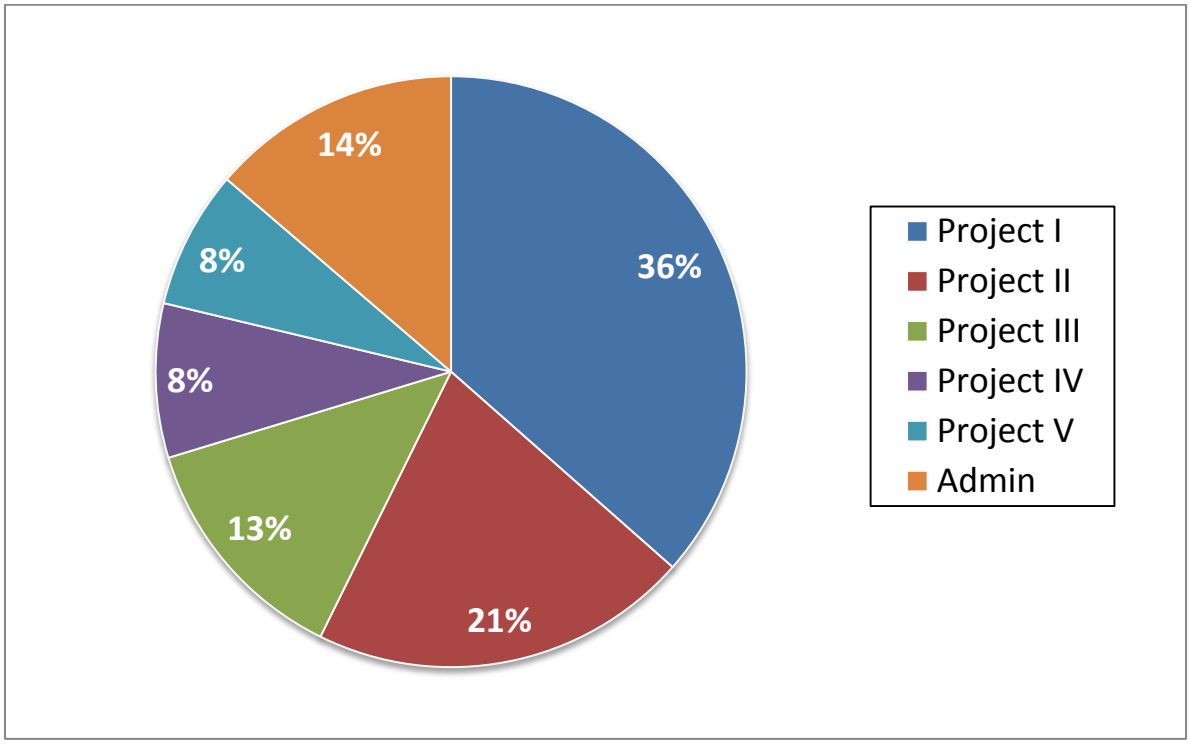
ENDING DATE MAY 2011

Appendix C. CAMRA Expenditures

CAMRA has now received a no-cost extension to 2013. Remaining budget from Nov. 2011 for the Center is $ 1.62 million. The last draw for this account was completed on 11/23/2011 for $100,000.

University	With Pending Total Spent	Percent of The Total
University of Arizona	$934,391.48	92
University of Michigan	$1,681,760.00	100
Northern Arizona University	$485,059.02	95
Drexel University	$1,739,393,97	81
University of California Berkeley	$768,472.96	89
Carnegie Mellon University	$269,043.00	100
Michigan State University	$2,498,449.72	71
Total	**$8,376,570.15**	**84**





PI	School
Project I	
Dr. Charles P. Gerba Dr. Christopher Choi	University of Arizona
Dr. Mark Nicas	University of California Berkeley
Dr. Syed Hashsham	Michigan State University
Dr. David Wagner	Northern Arizona University
Project II	
Dr. James Koopman Dr. Joseph Eisenberg	University of Michigan
Project III	
Dr. Charles N. Haas	Drexel University
Dr. Carol Bolin	Michigan State University
Project IV	
Dr. Patrick L. Gurian	Drexel University
Elizabeth Casman	Carnegie Melon University
Project V	
Dr. Rosina Weber	Drexel University
Administration	
Dr. Joan B. Rose	Michigan State University
Dr. Charles N. Haas	Drexel University

Appendix D. Quality Assurance Report

QUALITY ASSURANCE REPORT

Center for Advancing Microbial Risk Assessment
Year-6

Submitted by
Ms. Rebecca Ives
Quality Assurance Officer
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13 Natural Resources
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Submitted to

Dr. Irwin Baumel
U.S. Environmental Protection Agency (EPA)
National Center for Environmental Research
1025 F. Street, NW, Room 3500
Washington, D.C. 20004

And

Dr. Matthew Clark
Department of Homeland Security (DHS)
Washington DC

November 30, 2011

Background

According to the Quality Management Plan of the Center for Advancing Microbial Risk Assessment (CAMRA), each of the projects was to develop and implement a quality assurance project plan (QAPP) addressing the major elements contained in EPA guidance document, EPA QA/G-5 "Guidance for Quality Assurance Project Plans." With the exception of projects 2 and 5, the projects are subdivided by task among principal investigators. As a result, all projects except project 2 and 5 have multiple QAPPs covering the responsibilities and research objectives under the management of the principal investigator. The QAPPs have been given a numerical designation for organizational purposes. Each principal investigator is either the quality assurance manager for that location/task, or has designated personnel to act in that capacity.

TABLE A

Project	**QAPP #**	**PI**	**University**	**Current QAPP Title & Version**	Date QAPP Submitted to QAO	Date QAPP Approved by QAO	Date QAPP Approved by CAMRA directors
I	1	Chuck Gerba	AZ	QAPP P1Q1 Gerba V6_0.doc	10/30/11	10/30/11	**11/26/2011**
I	2	Chris Choi	AZ	QAPP P1Q2 Choi V6_0.doc	**9/13/2011**	**9/23/2011**	**9/28/2011**
I	3	Syed Hashsham	MSU	QAPP P1Q3 Hashsham v6_0.doc	**9/14/2011**	**9/23/2011**	**11/26/2011**
I	4	Mark Nicas	UCBerkeley	QAPP P1Q4 Nicas V6_0.doc	**9/12/2011**	**9/23/2011**	**11/26/2011**
I	5	David Wagner - QA	NAU	QAPP P1Q5 Wagner V6_0.doc	**09/12/11**	**09/23/11**	**11/26/2011**
II	6	Jim Koopman - QA Joe Eisenberg (Joseph Pujol)	UM	QAPP P2Q6 Koopman v6_0.doc	**09/10/11**	**09/12/11**	**9/28/2011**
III	7	Chuck Haas	Drexel	QAPP P3Q7 Haas V6_0.doc	**9/14/2011**	**9/16/2011**	**11/26/2011**
III	8	Carole Bolin	MSU	QAPP P3Q8 Bolin V6_0.doc	11/14/2011	**11/14/11**	**11/26/2011**
IV	9	Patrick Gurian	Drexel	QAPP P4Q9 Gurian V6_0.doc	**10/5/2011**	**10/5/2011**	**11/26/2011**
IV	10	Liz Casman	CMU	QAPP P4Q10 Casman v6_0.doc	**9/9/2011**	**09/12/11**	**9/28/2011**
V	11	Rosina Weber	Drexel	QAPP P5Q11 Weber v6_0.doc	**11/11/11**	**11/11/11**	**11/26/2011**

Audits

In 2011, all PIs except for Dr Casman conducted technical systems self audits. The Quality Assurance Officer (QAO) received and reviewed all completed audits. The QAO returned audit exit documents to all Quality Assurance Managers(QAM). Audit exit documents either noted self audit responses as acceptable or provided an itemized list of quality concerns to be addressed by the QAM. The quality managers were asked to respond to each item in writing. Both documents from every audit are archived by the QAO, along with notes and supporting materials provided by project personnel during audits.

Project	University	Lead PI	QA manager	**2011 Audit Response Dates**	QAPP #
I	AZ	Dr. Charles Gerba	Dr. Gerba	November 10, 2011	P1Q1
	AZ	Dr. Chris Choi	Dr. Choi	October 4, 2011	P1Q2
I	MSU	Dr. Syed Hashsham	Dr. Hashsham	October 3, 2011	P1Q3
I	UCBerkeley	Dr. Mark Nicas	Dr. Nicas	September 22, 2011	P1Q4
I	NAU	Dr. David Wagner	Dr. David Wagner	November 14, 2011	P1Q5
II	UM	Dr. James Koopman	Dr. Koopman	November 2, 2011	P2Q6
III	Drexel	Dr. Charles N. Haas	Mark Weir	October 14, 2011	P3Q7
III	MSU	Dr. Carole Bolin	Dr. Bolin	November 14, 2011	P3Q8
IV	Drexel	Dr. Patrick Gurian	Dr. Gurian	November 14, 2011	P4Q9
IV	CMU	Dr. Elizabeth Casman	Dr. Casman	September 16, 2011	P4Q10
V	Drexel	Dr. Rosina Weber	Dr. Weber	November 11, 2011	P5Q11

Audit findings

1. For most projects, although there have been some delays , work is progressing according to the schedules described in the QAPPs
2. For projects 1 and 2, some work objectives have either not been completed or have not yet been initiated and may be dropped.
3. With the exception of Project 5, QAPPs remained largely unchanged between year 5 and year 6. Changes usually entailed personnel updates.

The following section details the major quality improvements that projects have been asked to implement.

P1Q1

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

PI indicated that the research objectives for the survival of a selected arena virus, and aiding Dr. Choi's group in conduct of coliphage MS-2 and PRD-1 (or P22) in model water distribution system and aiding Dr. Nicas in indoor transport studies had not yet been completed.

P1Q2

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

P1Q3

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

P1Q4

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

P1Q5

The audit noted minor updates that should be listed in the QAPP regarding frequency of documentation of refrigerator temperatures.

Audit recommendations included completion of annual calibration of thermometers and balance

P2Q6

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

Project 2 tasks were delayed in part due to serious health problems of project personnel. PI indicated that the following objectives are not likely to be completed:

1) Develop EITS Models - Predict intervention effects in venues
2) Develop EITS Models - Predict population effects of interventions
3) Assess and document EITS model assumptions & observational or experimental data patterns – required data sets were not available
4) Develop statistical analysis methods to estimate EITS model parameters - Assess prediction bias of current best statistics
5) Develop statistical analysis methods to estimate EITS model parameters - Assess prediction bias of DC EITS based estimation methods
6) Design experimental and observational studies to estimate EITS model parameters - Adapt EITS models to CDC NPI Flu trials and control of MRSA in the SICU
7) Design experimental and observational studies to estimate EITS model parameters – List feasible NPI and MRSA control in the ICU trial design alternatives by cost
8) Design experimental and observational studies to estimate EITS model parameters - Assess hypothesis test power by study design
9) Design experimental and observational studies to estimate EITS model parameters - List inferences to be made from NPI and MRSA control trial results
10) Design experimental and observational studies to estimate EITS model parameters -

P3Q7

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

P3Q8

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

P4Q9

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

P4Q10

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

P5Q11

Audit responses to all items in the self audit were acceptable and no corrections were requested by the CAMRA Quality Assurance Officer

Changes were made to Project 5's QAPP to reflect the additional tasks involved with constructing the CAMRA Wiki.

Appendix E. CAMRA 6-Year Publications (Peer reviewed journals) Citations by Google Scholar

CAMRA has published or has in press 44 papers to date with 247 citations.

Rose

1. Masago, Y., T. Shibata, and J. B. Rose. 2008. Bacteriophage P22 and *Staphylococcus aureus* Attenuation on Nonporous Fomites as Determined by Plate Assay and Quantitative PCR. *Applied and Environmental Microbiology* 74(18):5838-5840. [1]

2. Jones, R.M., Masago, Y., Bartrand, Haas, C.N., Nicas, M., and J.B. Rose. (2009) Characterizing the risk of infection from *Mycobacterium tuberculosis* in commercial passenger aircraft using quantitative microbial risk assessment. *Risk Analysis*. 29, page 355. [7]

3. Razzolini, M.T.P., Weir, M.H. Matte, M.H., Matte, G.R., Fernandes, L.N. Rose, J.B. (2011). Risk of *Giardia* infection for drinking water and bathing in a peri-urban area in St. Paulo, Brazil. *International Journal of Environmental Health Research,* 21(3), 222-234.[0]

4. Weir, M.H.; Razzolini, M.T.P.; Masago, Y and Rose, J.B. IN PRESS. Water Reclamation Redesign for Reducing *Cryptosporidium* Risks at a Recreational Spray Park using Stochastic Models. *Water Research:* Accepted for Publication

Project I

Gerba

5. Boone, S. A. and C. P. Gerba 2007. The significance of fomites in the spread of respiratory and gastrointestinal disease. *Applied and Environmental Microbiology*, 73:1687-1696. [58]

6. Sinclair, R., S. A. Boone, D. Greenberg, P. Keim, and C. P. Gerba. 2008. Persistence of Category A select agents in the environment. *Appl. Environ. Microbiol.* 74:555-563. [28]

7. Ryan, G. G. Sinclair, C. Y. Choi, M. R. Riley and C. P. Gerba. 2009. Pathogen surveillance through monitoring of sewer systems. *Adv. Appl. Microbiol*. 65:249-269. [11]

8. Sinclair, R., Gomez, P.R., Choi, C.Y., Gerba, C.P. (2009) Assessment of MS-2 phage and salt tracers to characterize axial dispersion in water distribution systems. *Journal of Environmental Science and Health*.44: 963-971. [1]

9. Kim M., C. Y. Choi, and C. P. Gerba, 2008, Source Tracking of Microbial Intrusion in Water Systems Using Artificial Neural Networks, *Water Research,* 42:4-5, 1308-1314. **[9]**

Choi

10. Romero-Gomez, P., C. K. Ho, and C. Y. Choi. 2008. Mixing at Cross Junctions in Water Distribution Systems – Part I. A Numerical Study. ASCE *Journal of Water Resources Planning and Management* 134(3):284-294. [11]

11. Austin, R. G., B. van Bloemen Waanders, S. McKenna and C. Y. Choi. 2008. Mixing at Cross Junctions in Water Distribution Systems – Part II. An Experimental Study. ASCE *Journal of Water Resources Planning and Management* 134(3):295-302. [12]

12. Song, I.H., P. Romero-Gomez, and C. Y. Choi, 2009, Experimental Verification of Incomplete Solute Mixing in a Pressurized Pipe Network with Multiple Cross Junctions, *ASCE Journal of Hydraulic Engineering*, 135:11, 1005-1011. **[2]**

13. Yoon, J.-Y., J.-H. Han, C. Y. Choi, M. Bui, R. G. Sinclair, 2009, Real-Time Detection of Escherichia coli in Water Pipe Using a Microfluidic Device with One-Step Latex Immunoagglutination Assay, *Transactions of the ASABE*, 52(3), 1031-1039. **[4]**

14. Romero-Gomez, P., K. E. Lansey, C. Y. Choi, 2011, Impact of an incomplete solute mixing model on sensor network design, *Journal of Hydroinformatics* (in press).

15. Romero-Gomez P. and C. Y. Choi, 2011, Axial Dispersion Coefficients in Laminar Flows of Water Distribution Systems. *ASCE Journal of Hydraulic Engineering* (in press).

Hashsham

16. Herzog AB, McLennan SD, Pandey AK, Gerba CP, Haas CN, Rose JB, Hashsham SA.(2009). Implications of Limits of Detection of Various Methods for *Bacillus anthracis* in Computing Risk to Human Health. *Applied Environmental Microbiology*. 75:6331-6339. [5]

Nicas

17. Jones R. and Nicas, M, (2009) Experimental Determination of supermicrometer particle fate subsequent to a point release within a room under natural and forced mixing. *Aerosol Science and Technology*. 43: 921-938. [2]

Wagner

18. Greenberg, D. L., J. D. Busch, D. M. Wagner and P. Keim (2010). "Identifying experimental surrogates for *Bacillus anthracis* spores: a review." *Investigative Genetics* 1(4).[3]

Project II
Eisenberg

19. Pujol JM, Eisenberg JE, Haas CN, Koopman JS, 2009 The Effect of Ongoing Exposure Dynamics in Dose Response Relationships. *PLoS Comput Biol* 5(6): e1000399. doi:10.1371/journal.pcbi.1000399. [9]

20. Bryan T. Mayer, James S. Koopman, Edward L. Ionides, Josep M. Pujol, and Joseph N. S. Eisenberg. A dynamic dose–response model to account for exposure patterns in risk assessment: case study in inhalation anthrax. *J. R. Soc. Interface* 6 April 2011 vol. 8 no. 57 506-517 [0]

21. Li, S., J. Eisenberg, Spicknall, I.,and J. Koopman.Dynamics and Control of Infections Transmitted from Person to Person Through the Environment. *Am. J. Epidemiol. (2009) 170 (2): 257-265.* [7]

22. Spicknall, I., J. Koopman, M. Nicas, J. Pujol, L. Sheng and J. Eisenberg (2010). "Informing Optimal Environmental Influenza Interventions: How the Host, Agent, and Environment Alter Dominant Routes of Transmission." *PLoS Computational Biology* 6(10).[2]

23. Zelner, J., A. A. King, C. L. Moe and J. N. S. Eisenberg (2010). "How Infections Propagate After Point Source Outbreaks: An Analysis of Secondary Norovirus Transmission." *Epidemiology* 21(5): 711-718.[1]

Project III
Haas:

24. Bartrand, T. A., M. H. Weir, and C. N. Haas. 2008. Dose-Response Models for Inhalation of *Bacillus anthracis* Spores: Interspecies Comparisons. Risk Analysis 28(4):1115-1124. [18]

25. Tamrakar, S.B. and C. N. Haas. 2008. Dose-Response Model for Lassa Virus. Human and Ecological Risk Assessment 14(4): 742-752. [2]

26. Tamrakar, S.B. and C. N. Haas. 2008. Dose-Response Model for *Burkholderia pseudomallei* (melioidosis). Journal of Applied Microbiology 105(5):1361-1371. [2]

27. Weir, M. H. and C. N. Haas. Quantification of the Effects of Age on the Dose Response of *Variola major* in Suckling Mice. Human and Ecological Risk Assessment. [1]

28. Huang, Y., Bartrand, T.A., Haas, C.N. and Weir M.H. (2009) Incorporating Time Post Inoculation into a Dose-Response Model of *Yersinia pestis* in Mice. Journal of Applied Microbiology. 107(3):727-735. [7]

29. Huang, Y. and Haas, C.N. (2009) Time-dose-response Models for Microbial Risk Assessment. *Risk Analysis.* 29(5): 648-661. [10]

30. Huang, Y. and C. N. Haas (2011). "Quantification of the relationship between bacterial kinetics and host response for monkeys exposed to aerosolized *Francisella tularensis*." Applied and Environmental Microbiology. 77 (2), 485-490. [0]

31. Huang, Y., T. Hong, T. A. Bartrand, P. L. Gurian, C. N. Haas, R. Liu and S. B. Tamrakar (2010). "How Sensitive Is Safe? Risk-Based Targets for Ambient Monitoring of Pathogens." *IEEE Sensors Journal* 10(3): 668-673.[5]

32. Tamrakar, S. B., A. Haluska, C. N. Haas and T. A. Bartrand (2011). "Dose-Response Model of*Coxiella burnetii*(Q Fever)." *Risk Analysis*. 31(1), 120-128. [0]

33. Tamrakar S.B. and C.N. Haas. (2011) Dose-Response Model for Rocky Mountain Spotted Fever (RMSF) for Human. *Risk Analysis*.31(10), 1610-1621.[1]

34. Teske S.S., Huang, Y., Bartrand, T.A., Tamrakar, S.B., Weir, M.H. and Haas, C.N. (2011) "Animal and Human Dose Response Models for *Brucella* species," *Risk Analysis*,Oct;31(10):1576-96. [1]

35. Kitajima, M., Huang, Y., Watanabe T., Katayama H. and Haas, C.N. (2011) "Dose-Response Time Modeling for Highly Pathogenic Avian Influenza A (H5N1) Virus Infection," *Letters in Applied Microbiology*. 53(4), 438–444. [0]

Project IV
Gurian:

36. Corella-Barud, V., K.D. Mena, S.G. Gibbs, P.L. Gurian, and A. Barud. (2009). Evaluation of Neighborhood Treatment Systems for Potable Water Supply. *International Journal of Environmental Health Research*, 19(1):49-58. [2]

37. Hong, T., P. L. Gurian and N. Ward (2010). "Setting Risk-Informed Environmental Standards for Bacillus Anthracis Spores." *Risk Analysis* 30(10): 1602-1622.[3]

38. Mitchell-Blackwood, J., P. L. Gurian and C. O'Donnell (2011). "Finding Risk-based Switchover Points for Response Decisions for Environmental Exposure to *Bacillus anthracis*" submitted to Human and Ecological Risk Assessment." *Human and Ecological Risk Assessment*. 17(2), 489-509. [2]

39. Solon, I., P.L. Gurian, H. Perez. "The Extraction of a *Bacillus anthracis* Surrogate from Pleated HVAC Filter Samples," *Indoor and Built Environment* (in press).

Casman:

40. Casman, E. A. and B. Fischhoff. 2008. Risk Communication Planning for the Aftermath of a Plague Bioattack. *Risk Analysis* 28(5): 1327-1342. [6]

41. Durham D.P.and Casman, E. A. (In Press) Threshold Conditions for Bubonic Plague Persistence in Urban Rats. *Risk Analysis*.

Project V
Weber:

42. Rosina O. Weber, Marcia L. Morelli, Michael E. Atwood and Jason M. Proctor. Designing a Knowledge Management Approach for the CAMRA Community of Science. U. Reimer and D. Karagiannis (Eds.): PAKM 2006, *LNAI* 4333, pp. 315–325. [7]

43. Weber, R. O. "Addressing Failure Factors in Knowledge Management," (2007). *Electronic Journal of Knowledge Management*, 5(3): pp. 333-346. [11]

44. Gunawardena, S., R. Weber and D. E. Agosto (2010). "Finding that Special Someone: Modeling Collaboration in an Academic Context." *Journal of Education for Library and Information Science* 51(4).[3]