Center for Advancing Microbial Risk Assessment
Final Annual Report (Year 7)

Submitted to

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Introduction:

The Center for Advancing Microbial Risk Assessment (CAMRA) has finished it's work under the EPA star grant funded from 2005 ending March, 2013. CAMRA had two missions: the first

- to develop models, tools and information that will be used in a credible risk assessment framework to reduce or eliminate health impacts from deliberate use of biological agents of concern in the indoor and outdoor environment.

To accomplish this first objective 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 worked together within the (quantitative microbial risk assessment) QMRA framework completing and publishing a total of 52 journal articles with 434 citations during the past six years (Figure 1 shows the key projects and number of papers and Appendix A has the complete list of publications). Nineteen 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 CAMRA projects.

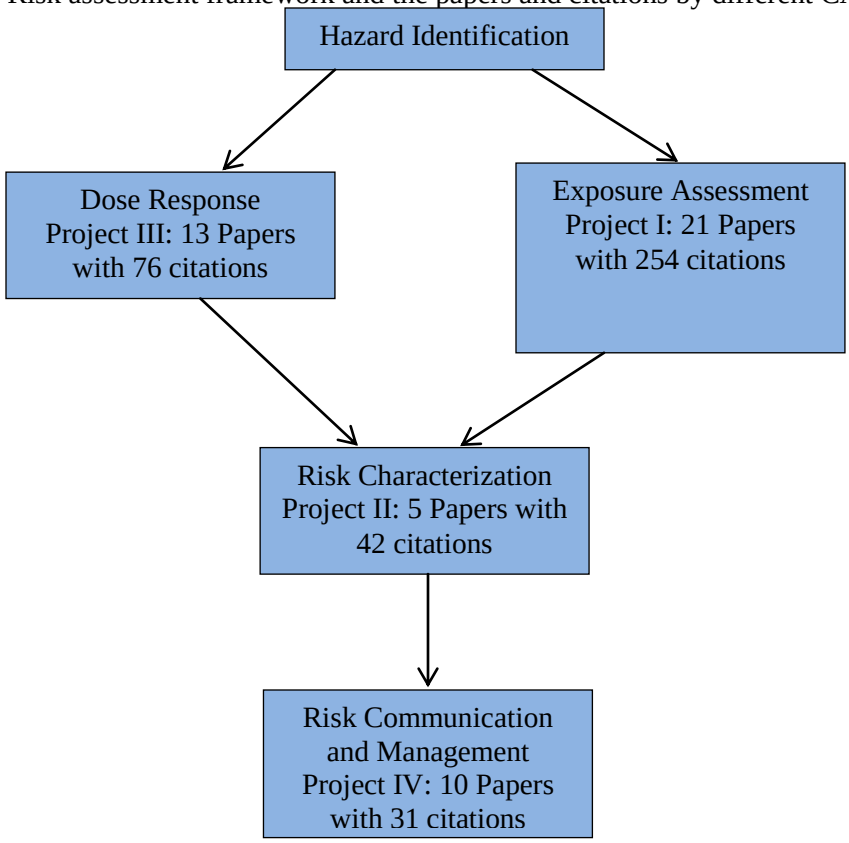
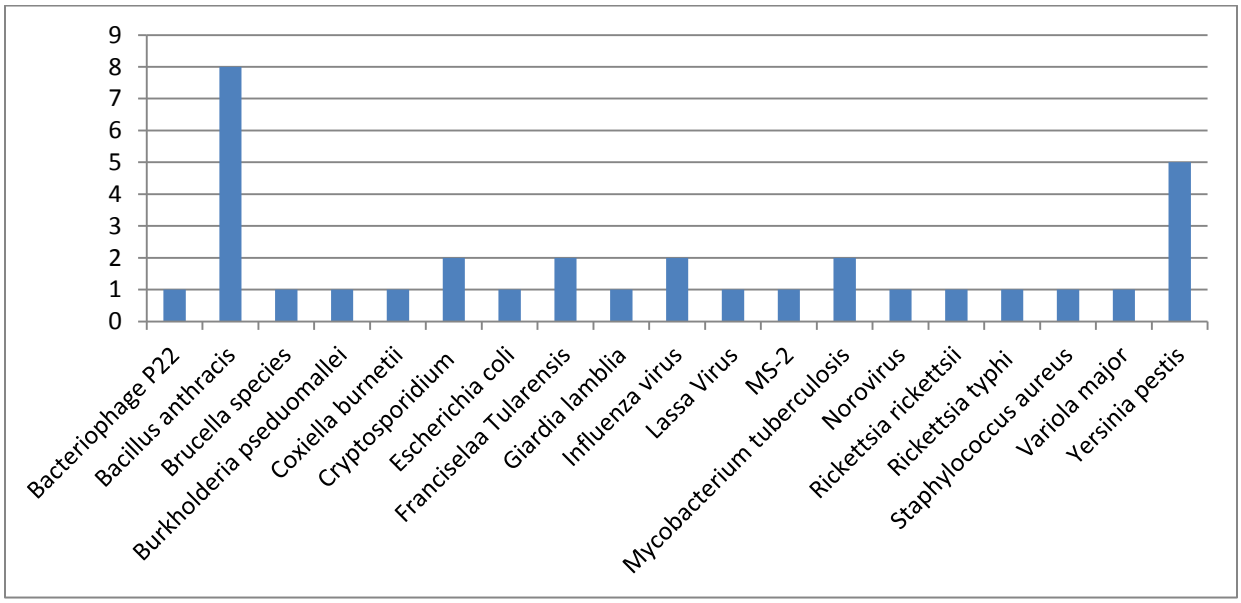


Figure 2. Number of CAMRA papers with each stated pathogen or indicator (excluding review articles).



The second missions was to

- to build a national network for microbial risk knowledge management, learning and transfer, for the community of scientists, and students via educational programs and community of professionals in the field and in our communities.

This has been accomplished through the QMRA summer institutes and the last year and the final few months will focus on adding to our knowledge system, the QMRAwiki. Appendix B. has some screen shots of some of the key components of the QMRAwiki including landing pages for Hazard ID; Dose Response; Exposure; Risk Characterization; Risk Management; and finally the QMRA calculator. http://wiki.camra.msu.edu/index.php?title=Quantitative_Microbial_Risk_Assessment_(QMRA)_Wiki

Summary of Key Findings and Accomplishments

CAMRA's high productivity after six 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 (2011-2012) through 23 publications (See Appendix A) and 15 presentations. The next generation of QMRA students have graduated and entering the workforce. Dr. Jade Mitchell and Dr. Mark Weir have both recently joined Michigan State University and Temple, respectively as assistant professors.

CAMRA will finalize publications (9 in review, revision or preparation, see Appendix A) and models for year as most of the outputs are in the shape of paper being in preparation or being reviewed.

Table 1 below quantifies some key accomplishments for 2011-12

Accomplishment Type	Amount
Peer reviewed publications	23
Peer reviewed proceedings	2
Master's theses	1
Doctoral dissertations	1
Conference presentations	15
Supported students	13
Students graduated	2

CAMRA Project I have completed their work on fomite-human exposure pathways addressing 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. Project I also examined the effect of low and high relative humidity on bacterial and viral survival on several common inanimate surfaces (fomites). 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 influenced by distance and force of the coughing.

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.

Digital LAMP has been investigated as a method and the environmental detection limits to address various levels of risk have been explored. The 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 carying 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 this "digital LAMP" approach is to experimentally test this hypothesis.

Project I team members have used metagenomics approaches to address fomite contamination and hazard discovery for viruses finding that a wide array of bacteriophage are likely targets for further work to improve exposure assessment. 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 designed to target conserved regions surrounding hyper-variable regions of relevant genes will be used to amplify the 16S rRNA sequences and sequenced by high throughput sequencing. Signature sequences found with 454 Sequencing Technology will be evaluated for the presence of pathogenic and non-pathogenic organisms on the fomites.

For drinking water pathways 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 and embedded axial dispersion into the AZRED code in order to fully integrate both of the improved transport assumptions for water quality analyses.

Project II have used a deterministic differential equation based model to describe the hand and environmental mediated transmission of Methicillin-resistant Staphylococcus aureus (MRSA). Project II

conducted research on modeling influenza transmission on a college campus. Local weather variables were found to be statistically significant in association with the proportion of cases that tested positive for influenza virus, and the proportion of diagnosis in outpatients visiting Hong Kong influenza surveillance sites. Project II examined the successes and shortcomings of polio eradication using a transmission modeling analysis.

Project III, has added to the impressive dose-response models developing models for *Brucella* species *Leptospira* bacteria, *Rickettsia rickettsii* , *Rickettsia typhi* 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. Human health risks posed by *Aspergillus fumigatus* and risk mode; for inhaled toxins associated with spores of *Stachy* are in progress.

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 published in 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 major accomplishment of the year 2011-2012 is the QMRAwiki,a collaborative work among all CAMRA projects
http://wiki.camra.msu.edu/index.php?title=Quantitative_Microbial_Risk_Assessment_(QMRA)_Wiki

Currently CAMRA wiki contents include an over view of 25 different pathogens and 39 completed dose response models (bacteria, viruses, protozoa and prion). Exposure assessment, risk characterization and risk management sections have been constructed and content is being added. . Dose-response Calculator, persistent models are significant features in wiki. Currently the dose-response models have been compiled in a dose response monograph. The final review has been undertaken and this will be available for purchase by the end of the year.

Many organizations are adopting wiki technology to facilitate information management and collaborations. While many studies have tried to identify factors that facilitate or impede wiki adoption, the results have been mixed. Some factors may facilitate wiki adoption in one organization, but is found to impede adoption in another organization. Through a review of existing literature, key communication scientists (Dr. Jonathan Obar and Dr. Maria Lainski working with CAMRA) argue that the mixed results may be caused by lumping wikis used for information management purposes with wikis used for collaborative communication purposes. In order to better understand how factors contribute to wiki adoption, it is vital to make the conceptual distinction between long-term information management wikis and short-term collaborative communication wikis for wiki researchers and designers. CAMRA will continue to explore how these concepts can advance QMRA knowledge, use and contributions.

Appendix A.
CAMRA has published or has in press 54 papers to date with 434 citations.
(citations are shown in []) Listed by each lead investigator.

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. [3]

2. Jones, R.M., Y. Masago, T. Bartrand, C.N. Haas, M. Nicas, 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(3):355-365. [12]

3. Razzolini, M.T.P. M.H. Weir. M.H. Matte, G.R. Matte, L.N. Fernandes and J.B. Rose. (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.; M.T.P. Razzolini, Y. Masago, and J.B. Rose. (2011). Water Reclamation Redesign for Reducing *Cryptosporidium* Risks at a Recreational Spray Park using Stochastic Models. *Water Research,* 45(19):6504-6514[0]

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. [83]

6. 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. [16]

7. Sinclair, R., S. A. Boone, D. Greenberg, P. Keim, and C. P. Gerba. (2008). Persistence of Category A select agents in the environment. *Applied Environmental Microbiology*, 74:555-563. [42]

8. Ryan, G, G. Sinclair, C. Y. Choi, M. R. Riley and C. P. Gerba. (2009). Pathogen surveillance through monitoring of sewer systems. *Advanced Applied Microbiology*, 65:249-269. [12]

9. Sinclair, R., P.R. Gomez, C.Y. Choi, C.P. Gerba. (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]

10. Sinclair, R., J. B. Rose, S. A. Hashsham, C. P. Gerba and C. N. Haas. (2012). Selection of microbial surrogates for studying the fate and control of pathogens in the environment. *Applied Environmental. Microbiology*, 78:1969-1977 [2]

11. Ahamd, F., S. K. Pandey, A. B. Herzog, J. B. Rose, C.. P. Gerba and S. A. Hashsham. (2012). Environmental applications and potential health implications of quantum dots. *Journal of Nanoparticle Research*, 14:1038

12. Herzog, A.B., A. K. Pandey, D. Reyes-Gasteul, C. P. Gerba, J. B. Rose and S. A Hashsham. 2012. Evaluation of sample recovery for bacteriophage P22 on fomites. *Applied Environmental. Microbiology*, 78:7915-7922.

Choi

13. 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. [18]

14. 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. [22]

15. 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. [5]

16. Yoon, J.-Y., J.-H. Han, C. Y. Choi, M. Bui, and R. 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. [5]

17. Romero-Gomez, P., K. E. Lansey, and C. Y. Choi. (2011). Impact of an incomplete solute mixing model on sensor network design, *Journal of Hydroinformatics*, 13(4):642.651.

18. Romero-Gomez, P. and C. Y. Choi. (2011). Axial Dispersion Coefficients in Laminar Flows of Water Distribution Systems. *ASCE Journal of Hydraulic Engineering* , 137(11):1500-1508.[3]

Hashsham

19. Herzog, A.B., S.D. McLennan, A.K. Pandey, C.P. Gerba, C.N. Haas, J.B. Rose, and S.A. Hashsham. (2009). Implications of Limits of Detection of Various Methods for *Bacillus anthracis* in Computing Risk to Human Health. *Applied Environmental Microbiology. 75:6331-633*9. [16]

Nicas

20. Jones, R. and M. Nicas. (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

21. 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.[12]

Project II
Eisenberg

22. Pujol, J.M., J.N. Eisenberg, C.N. Haas, and J.S. Koopman. (2009). The Effect of Ongoing Exposure Dynamics in Dose Response Relationships. *PLoS Computational Biology*, 5(6): e1000399. doi:10.1371/journal.pcbi.1000399. [14]

23. Mayer, B.T., J. S. Koopman, E. L. Ionides, J. M. Pujol, and J. N. Eisenberg. (2011). A dynamic dose–response model to account for exposure patterns in risk assessment: case study in inhalation anthrax. *Journal of Royal Society Interface*, 8:57 506-517 [0]

24. Li, S., J.N. Eisenberg, I. Spicknall, and J.S. Koopman. (2009). Dynamics and Control of Infections Transmitted from Person to Person Through the Environment. *American Journal of Epidemiology, 170 (2): 257-265.* [22]

25. Spicknall, I., J.S. Koopman, M. Nicas, J. Pujol, L. Sheng and J.N. Eisenberg. (2010). Informing Optimal Environmental Influenza Interventions: How the Host, Agent, and Environment Alter Dominant Routes of Transmission. *PLoS Computational Biology*, 6(10): e1000969.[3]

26. Zelner, J., A. A. King, C. L. Moe and J. N. Eisenberg. (2010). How Infections Propagate After Point Source Outbreaks: An Analysis of Secondary Norovirus Transmission. *Epidemiology*, 21(5): 711-718.[3]

Project III
Haas:

27. 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. [27]

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

29. Tamrakar, S.B. and C. N. Haas. (2008). Dose-Response Model for *Burkholderia pseudomallei* (melioidosis). *Journal of Applied Microbiology*, 105(5):1361-1371. [3]

30. 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*, 15(6):1245:1256 [1]

31. Huang, Y., T.A. Bartrand, C.N. Haas, and M.H. Weir. (2009). Incorporating Time Post Inoculation into a Dose-Response Model of *Yersinia pestis* in Mice. *Journal of Applied Microbiology*. 107(3):727-735. [9]

32. Huang, Y. and C.N. Haas, (2009) Time-dose-response Models for Microbial Risk Assessment. *Risk Analysis*, 29(5): 648-661. [15]

33. 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. [1]

34. 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.[8]

35. 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. [4]

36. 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.[3]

37. Teske S.S., Y. Huang, T.A. Bartrand, S.B. Tamrakar, M.H. Weir, and C.N. Haas. (2011). Animal and Human Dose Response Models for *Brucella* species. *Risk Analysis*, 31(10):1576-96. [2]

38. Kitajima, M., Y. Huang, T.Watanabe, H. Katayama and C.N. Haas. (2011). Dose-Response Time Modeling for Highly Pathogenic Avian Influenza A (H5N1) Virus Infection. *Letters in Applied Microbiology*, 53(4): 438–444. [1]

39. Tamrakar, S.B., Y. Hunag, and C.N. Haas. (2012). Dose-Response Model for Murine Typhus (*Rickettsia typhi*): Time Post Inoculation and Host Age Dependency Analysis. *BMC Infectious Disease*, 12:77.

Project IV
Gurian:

40. 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]

41. Hong, T., P. L. Gurian and N. Ward. (2010). Setting Risk-Informed Environmental Standards for Bacillus Anthracis Spores. *Risk Analysis*, 30(10): 1602-1622.[9]

42. 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): 489-509. [4]

43. Solon, I., P.L. Gurian, H. Perez. (2012). The Extraction of a *Bacillus anthracis* Surrogate from Pleated HVAC Filter Samples. *Indoor and Built Environment*, 21(4): 562-567. [1]

44. Hong, T. and P.L. Gurian. (2012). Characterizing Bioaerosol Risk from Environmental Sampling. *Environmental Science and Technology*, *46*(12):6714-6722.

45. Hong, T., P.L. Gurian, Y. Huang, and C.N. Haas. (2012). Prioritizing Risks and Uncertainties from Intentional Release of Selected Category A Pathogens. *PLoS ONE*, *7*(3):e32732.[2]

46. Mitchell-Blackwood, J., P. Gurian, R. Lee, and B.Thran. (2012). Variance in *Bacillus anthracis* Virulence Assessed through Bayesian Hierarchical Dose-Response Modeling. *Journal of Applied Microbiology, 113*(2):265-275. [1]

47. Ryan, M.O., P. J. Duzinsk, P. L. Gurian, C. N. Haas, and J.B. Rose. Accepted. Acceptable Microbial Risk: Benefit-Cost Analysis of a Boil Water Order for *Cryptosporidium*. (accepted by *Journal of American Water Works Association*)

Casman:

48. Casman, E. A. and B. Fischhoff. (2008). Risk Communication Planning for the Aftermath of a Plague Bioattack. *Risk Analysis,* 28(5): 1327-1342. [9]

49. Durham , D.P. and E. A. Casman. (2009). Threshold Conditions for Bubonic Plague Persistence in Urban Rats. *Risk Analysis,* 29(12):1655-1663.[3]

Project V
Weber:

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

51. Weber, R. O. (2007). Addressing Failure Factors in Knowledge Management. *Electronic Journal of Knowledge Management*, 5(3): 333-346. [21]

Gunawardena, S., R. O.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): 210-221.[3]

52. Weber, R.O. and Gunawardena, S. (2012). Representing Scientific Knowledge. Cognition and Exploratory Learning in the Digital Age. CELDA 2012

53. Gunawardena, S. and R. O. Weber. (2012). Reasoning with Organizational Case Bases in the Absence Negative Exemplars. 2nd Workshop on Process-Oriented Case-Based Reasoning, ICCBR-2012
conference paper

Peer review journal articles under review or in preparations

1. Lopez, G. U., C. P. Gerba, A. Tamimi, M. Kitajima, S. Maxwell, and J. B. Rose. (2012).Transfer efficiency of bacteria and viruses from porous and nonporous fomites to fingers under different relative humidity. In preparation.

2. Lopez, G. U., C. P. Gerba, A. Tamimi, M. Kitajima, S. Maxwell, K. A. Reynolds.(2012). Comparison of two approaches in determining transfer efficiency of *Escherichia coli* from nonporous fomites to fingers. In preparation

3. Lopez, G. U. C. P. Gerba, A. Tamimi, M. Kitajima and S. Maxwell. (2012). Survival of bacteria and viruses on surfaces under different humidity. In preparation.

4. Andrade, A., C.Y. Choi. (2012) Integration of incomplete mixing and axial dispersion into a single water quality modeler of water distribution systems, ***ASCE Journal of Environmental Engineering,*** in preparation.

5. Austin, R, A Andrade, C.Y. Choi. (2012) Experimental verification of combined axial dispersion and incomplete mixing during laminar flow in water distribution systems, ***ASCE Journal of Environmental Engineering,*** in preparation.

6. Hamilton, M., P. L. Gurian, E.A. Casman, and T. Hong. (2012) Responding to Re-aerosolization Risk in the Wake of a Wide-area Anthrax Release. (about to be submitted).

7. de Bruin, W.B., J. Downs, and E.A. Casman. (2012). Motivations to engage in flu prevention behaviors: The role of perceived effectiveness, difficulty, and concerns about self and others.(about to be submitted)

8. Tamrakar, S.B. and J.B. Rose. (2012). Dose Response analysis of *Pseudomonas aeruginosa*: an opportunistic pathogen. (In preparation).

9. Tamrakar, S.B. and C.N. Haas. (2012) Dose-Response Analysis of *Naegleria fowleri*. (under review).

10. Milbrath , M.O., I.H. Spicknall, J.L. Zelner, C.L. Moe and J.N.Eisenberg Heterogeneity in norovirus shedding duration affects community risk. *Epidemiology and Infection*.(In Review)

Published articles in the year 2011-2012

1. Ahamd, F., S. K. Pandey, A. B. Herzog, J. B. Rose, C. P. Gerba and S. A. Hashsham. (2012). Environmental applications and potential health implications of quantum dots. *Journal of Nanoparticle Research*, 14:1038

2. Gunawardena, S. and R. O. Weber. (2012). Reasoning with Organizational Case Bases in the Absence Negative Exemplars. 2nd Workshop on Process-Oriented Case-Based Reasoning, *ICCBR-2012*

3. Herzog, A.B., A. K. Pandey, D. Reyes-Gasteul, C. P. Gerba, J. B. Rose and S. A Hashsham. (2012). Evaluation of sample recovery for bacteriophage P22 on fomites. Applied Environmental Microbiology,78: 7915-7922

4. Hong, T. and P.L. Gurian. (2012). Characterizing Bioaerosol Risk from Environmental Sampling. *Environmental Science and Technology*, *46*(12):6714-6722

5. Hong, T., P.L. Gurian, Y. Huang, and C.N. Haas. (2012). Prioritizing Risks and Uncertainties from Intentional Release of Selected Category A Pathogens. *PLoS ONE, 7*(3):e32732.

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

7. Mayer, B.T., J. S. Koopman, E. L. Ionides, J. M. Pujol, and J. N. Eisenberg. (2011). A dynamic dose–response model to account for exposure patterns in risk assessment: case study in inhalation anthrax. *Journal of Royal Society Interface,* 8:57 506-517 [0]

8. Mayer B.T., J.N. Eisenberg, C.J. Henry, M.G.M. Gomes, E.L. Ionides J.S. Koopman. (2012). Successes and shortcomings of polio eradication: A transmission modeling analysis. *American Journal of Epidemiology*. (In Press)

9. Mitchell-Blackwood, J., P. Gurian, R. Lee, and B.Thran. (2012). Variance in *Bacillus anthracis* Virulence Assessed through Bayesian Hierarchical Dose-Response Modeling. *Journal of Applied Microbiology, 113*(2):265-275.

10. 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): 489-509.

11. Razzolini, M.T.P. M.H. Weir. M.H. Matte, G.R. Matte, L.N. Fernandes and J.B. Rose. (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.

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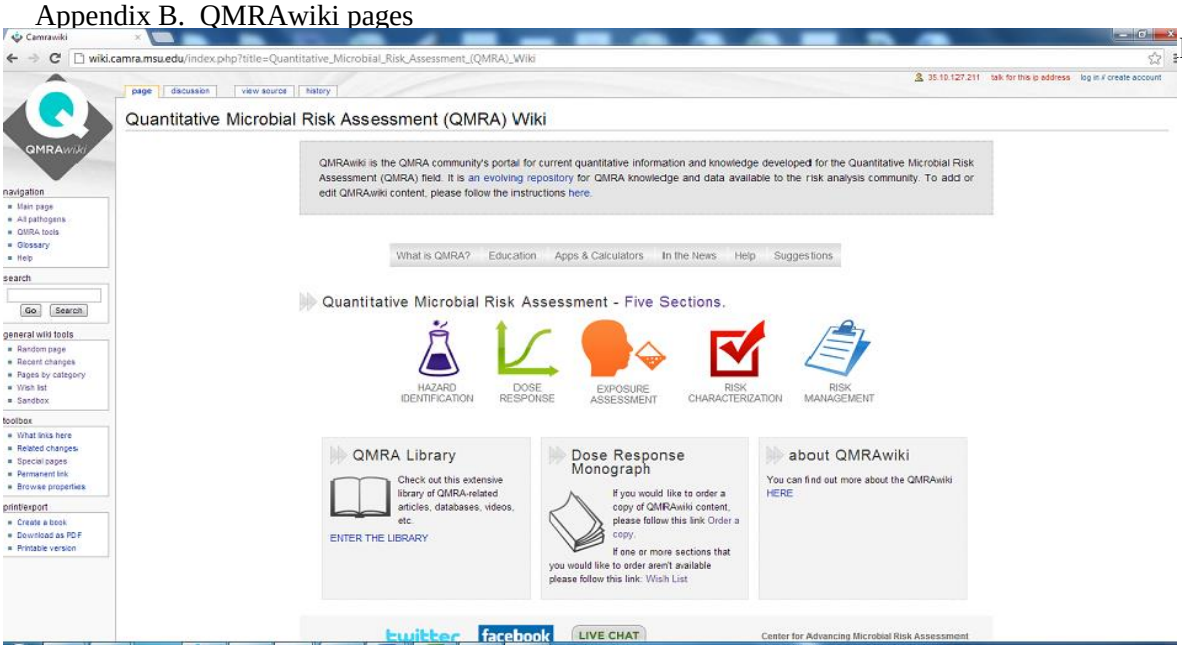
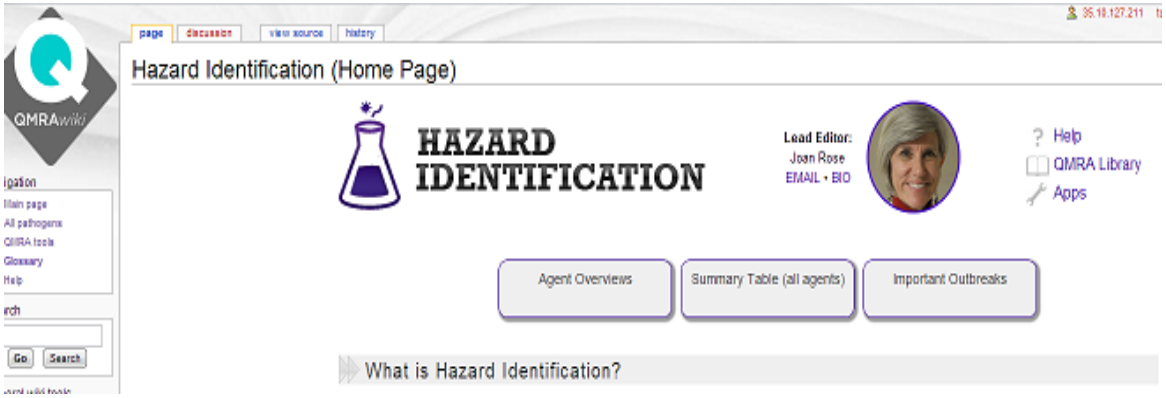
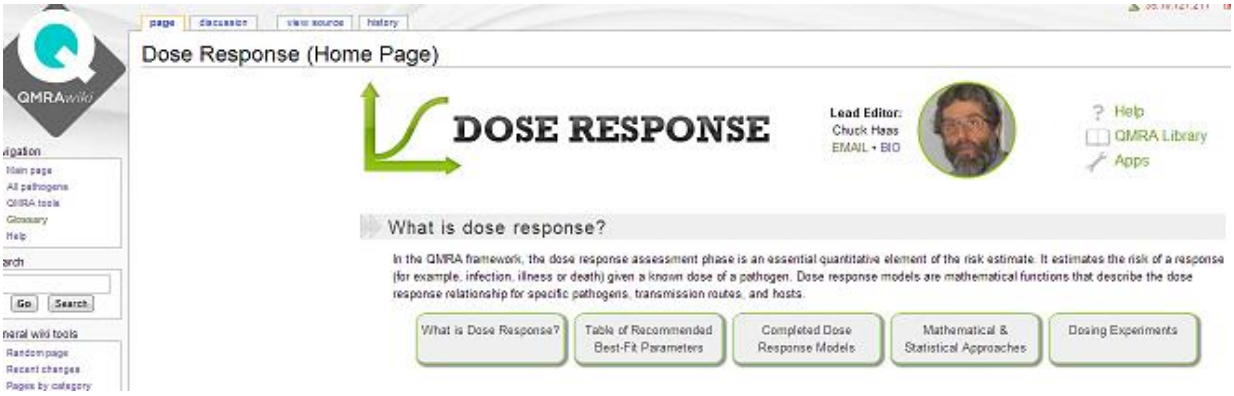
Appendix B. QMRAwiki pages



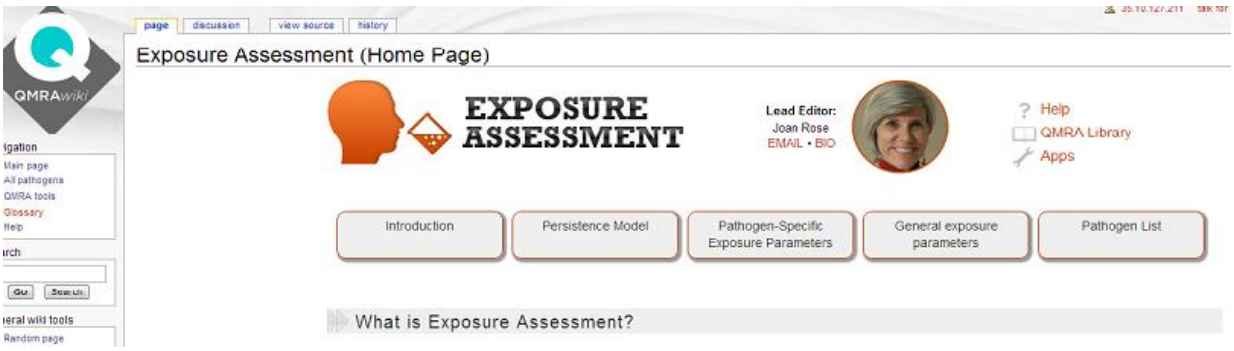
- **Hazard Identification**
  - Pathogen Overview
  - Summary Table (All agents
  - Important Outbreaks
    - Recreational Water Outbreak
    - Foodborne Outbreaks
    - Drinking Water Outbreaks



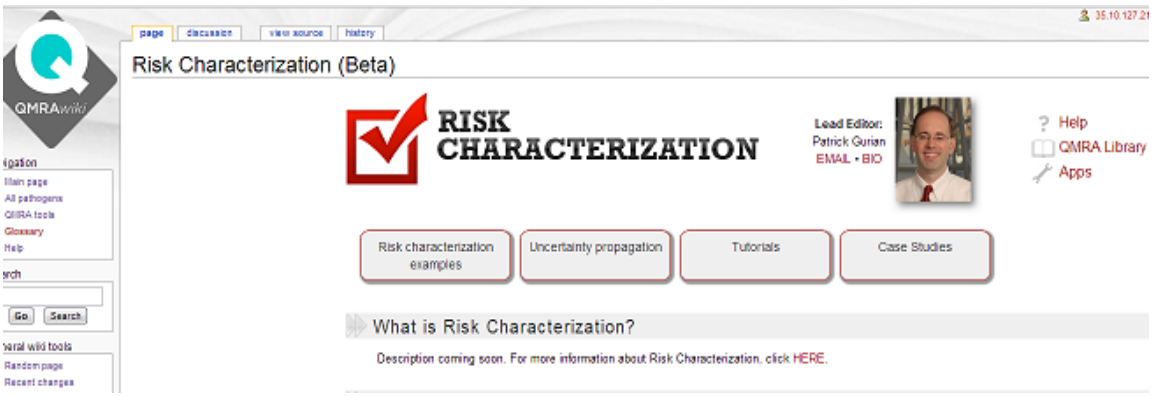
- **Dose Response Models**
  - Table of Recommended Best Fit Model/Parameters
  - Completed Dose Response Models
  - Mathematical and Statistical Approaches
  - Dosing Experiments



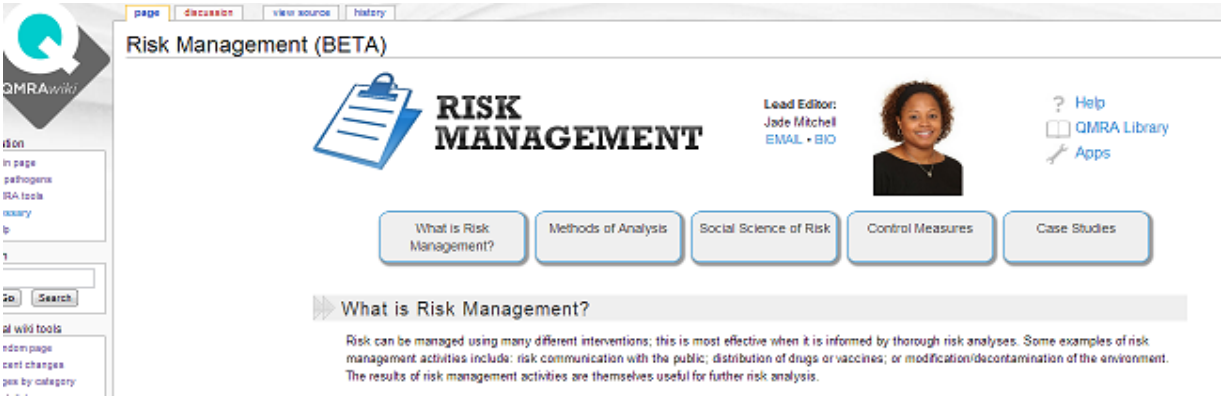
- **Exposure Assessment**
  - Persistence Models
  - Pathogen-Specific Exposure Parameters
  - General Exposure Parameters
    - Drinking Water
    - Recreation Water
    - Fomites
      - Recovery Efficiency
        - Recovery Efficiency from Fomites to Hand
        - Transfer Efficiencies from Hand-to-Mouth
      - Contact Rates
      - Survival on the Fomites



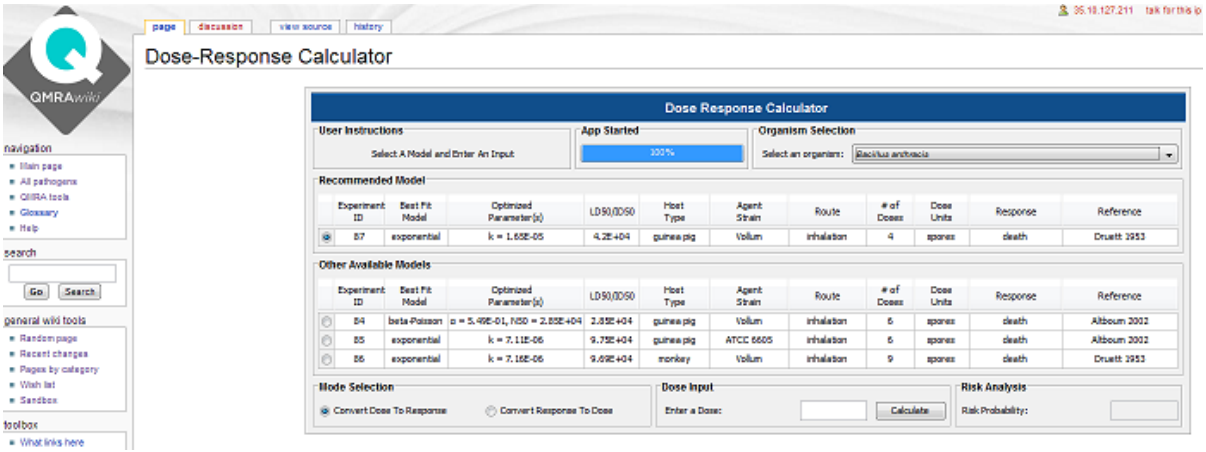
- **Risk Characterization**
  - Risk Characterization Examples
  - Uncertainty Propagation
  - Case Studies



- **Risk Management**
  - Methods of Analysis
  - Social Science of Risk
  - Control Measures
  - Case Studies



- **QMRA Tools**
  - Advanced Dose-Response Calculator
  - Basic Dose-Response Calculator



Appendix C. Budget Summary

A Total of $9,440,133.18 has been spent as of November, 2012. Current funding for the QMRAwiki and final publications will be supported by MSU and Drexel to March, 2013. All funds have been allocated.