Filtration Research at the Particle Technology Laboratory University of Minnesota

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Overview of the Particle Technology Laboratory

- **Founded late 1950's by the late Professor K. T. Whitby**
- **Immediate Past Director Regents' Prof. Benjamin Liu**
- **Current Director Professor David Y. H. Pui**
- **6 faculty members and 20 graduate students**
- **Graduated over 120 Ph.D.s and 300 M.S. students**
- **Published over 1,200 papers and reports**
- **Facilities: 15,000 sq.ft. lab space, cleanrooms, wind tunnel, filter testing, and vacuum facilities**
- **Develop instruments for particle measurement, sampling and generation in the 0.002 to 100 μm**
- **Offer annual short courses to aerosol practitioners**

Research Highlights

- Topics include: Nanoparticle Generation and Measurement; Air Pollution & Environmental Studies; Clean Rooms & Microcontamination Control; Gas & Liquid Filtration; Indoor Air Quality; Bioaerosols; Basic Aerosol Research & Instrumentation.
- Federal Agency Sponsors: NSF, DOE, NASA, EPA, NIOSH, DARPA, DHS.
- Industrial Sponsors: ASHRAE, EPRI, Microcontamination Research Consortium, Center for Filtration Research, Individual Companies.
- Annual Research Expenditure: Approx. $2.0 million

Research Capabilities and Accomplishments

- Develop more than 20 commercial instruments that are widely used for air pollution, process, and clean room measurements
- Research has been incorporated into codes and standards by NIST, ASHRAE, EPA, ASTM.
- Equipment to produce, sample, classify and measure aerosols of a variety of materials in the size range from 2 nm to 100 µm
- Wind tunnel and test facilities to study particle transport deposition, and filtration including bioaerosols
- Numerical codes to simulate flow fields and particle trajectories in different force gradients and in vacuum

CONTINUING PROFESSIONAL EDUCATION

- **“Aerosol and Particle Measurement” Short Course**
  - First offered in 1978
  - 32 offerings with more than 1,700 attendees from industry, government and academia
- **“Air and Gas Filtration” Short Course**
  - Developed under NSF support
  - First offered in 1995
  - 8 offerings with 300 attendees

Partnership with Industry

Center for Filtration Research (CFR)

- Established January, 1991
- 9 Current Company Members:
- 10 Ph.D.s and 10 M.S.s graduated, currently 4 graduate students and 1 post-doc
- 6 faculty investigators

Sample Filtration Projects

- **Dust Collector Recirculation for Industrial Operations**, ASHRAE, 1987
- **Matching Filtration to Health Requirements**, Phases I and II, ASHRAE, 1989 – 1993
- **Commercial Building HVAC Requirements for Maintaining Good Indoor Air Quality**, EPA, 1994-1998
- **Development of Optimum Filter Pleating Design**, CFR, 1998-2000.
- **Measurements of Dust Loading for Various Filter Types**, CFR, 2000-2005
- **Development of a Standard Method of Test for Commercial Kitchen Effluent Grease Removal Devices**: Fisher-Nickel, Inc., 2003-2004 (ASTM F2519-05)
- **Integrated Biological Data From Filter Samples In Buildings**, Dept. Homeland Security, 2004-2006

INTEGRATED BIOLOGICAL DATA FROM FILTER SAMPLES IN BUILDINGS

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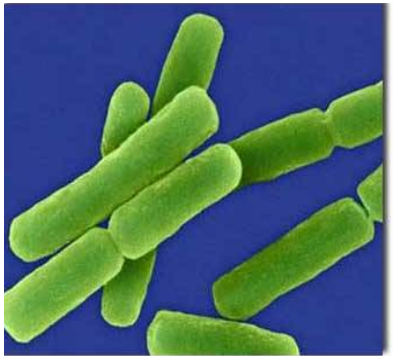
Outline of Presentation

- Objectives
- Approach
- Results
  - Captured bacteria identified
  - Captured viruses identified with RT-PCR
- Conclusions
- Future Work
- Acknowledgements

Objectives

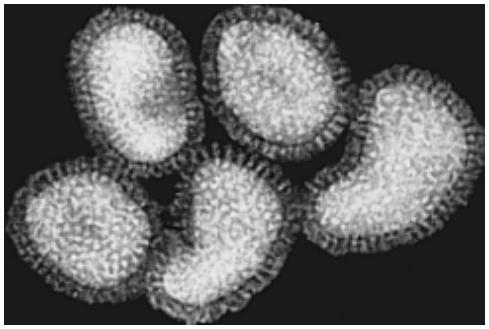
- Provide knowledge of normal background levels of bacteria and virus aerosols in and near large public buildings
- Look for targeted list of threat agents and their near neighbors (most likely at very low concentrations)
- Correlate results with environmental data (season of year, geographical location)

Targeted Bacteria



- *Bacillus anthracis*
- *Brucella spp.*
- *Burkholderia spp.*
- *Francisella tularenis*
- *Haemophilus influenzae*
- *Klebsiella pneumoniae*
- *Legionella pneumophila*
- *Micrococcus luteus*
- *Mycobacterium tuberculosis*
- *Mycoplasma pneumoniae*
- *Pseudomonas aeruginosa*
- *Staphylococcus aureus*
- *Streptococcus pneumoniae*
- *Streptococcus pyrogenes*
- *Yersinia pestis*

Targeted Viruses

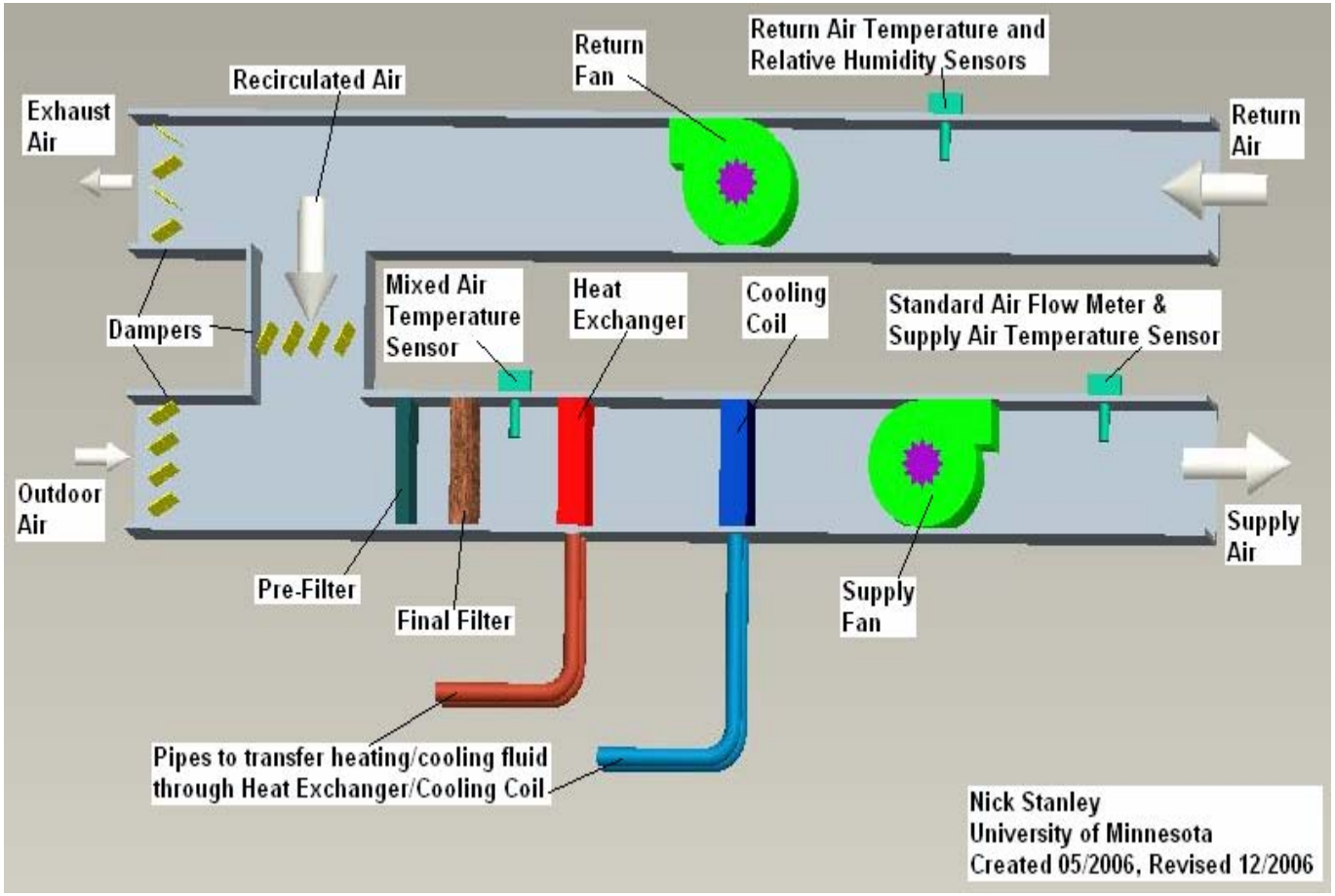


- Adeno virus
- Corona virus
- Eastern equine encephalitis virus
- Ebola virus
- Entero virus
- Influenza A virus
- Infuenza B virus
- Lassa fever virus
- Machupo virus
- Marburg virus
- Orthopox virus
- Parainfluenza virus I
- Parainfluenza virus II
- Parainfluenza virus III
- Parainfluenza virus IV
- Respiratory syncytial virus
- Rhino virus
- Venezuelan equine encephalitis virus
- Western equine encephalitis virus

Approach

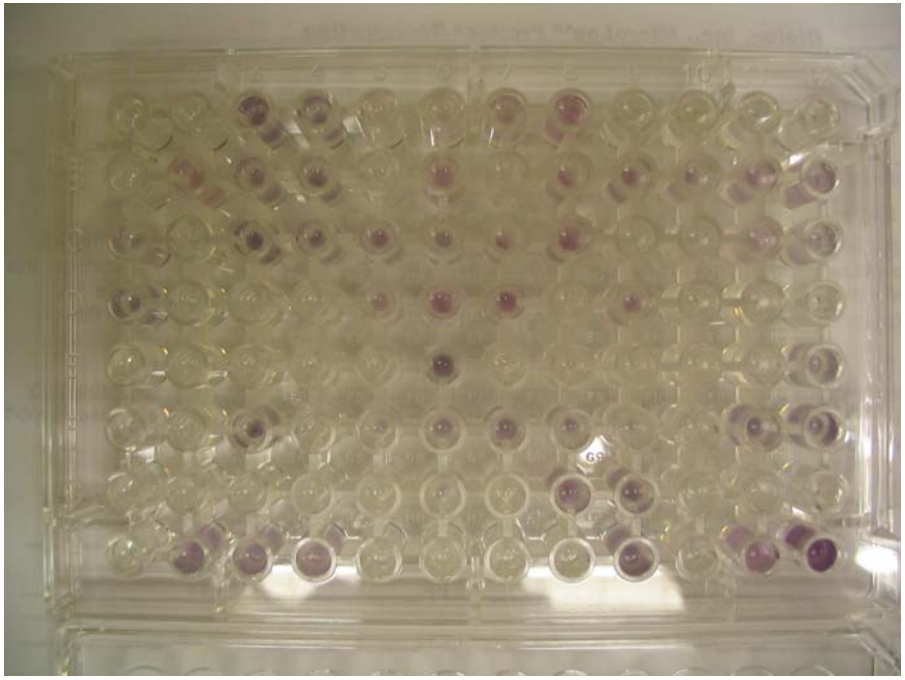
- Use pre-existing HVAC ventilation filters as high volume bioaerosol samplers in buildings
- Remove collected material from the filters and culture for bacteria
- Use Polymerase Chain Reaction (PCR) and Reverse Transcription Polymerase Chain Reaction (RT-PCR) to determine the presence of the targeted bacteria and virus

Typical Building Air Handling Unit



Identification of bacteria cultures using a Biolog Microstation

Photo of Biolog Microstation reader and computer controller



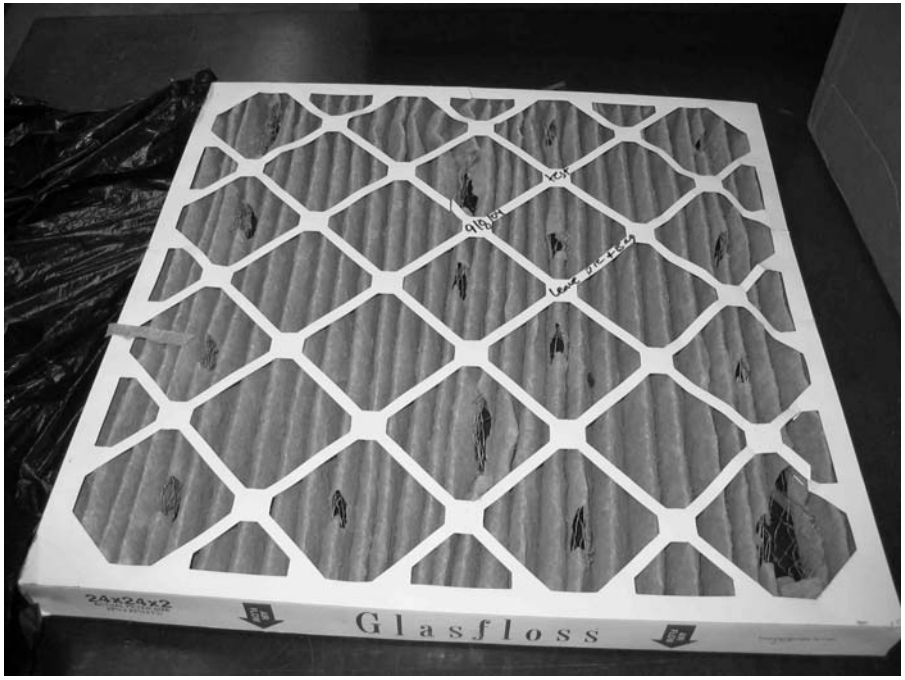
96 well plate with Biolog media showing color changes

Example primer selected for RT-PCR identification of Influenza A virus

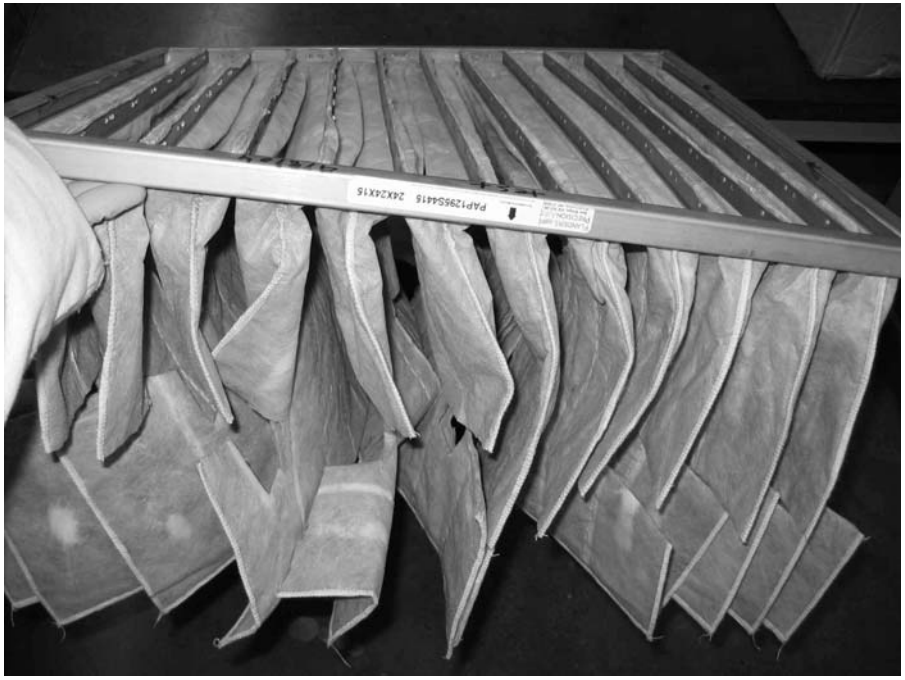
- Primer names: Influenza As, Influenza Aas
- Primer sequence:
  - 5’-AAA GCG AAT TTC AGT GTG AT-3’
  - R5’ GAA GGC AAT GGT GAG ATT T-3’
- Target region
  - NS gene
- Amplicon length (bp)
  - 104

Loaded full-size clean Viledon filters in ASHRAE 52.2 tunnel to test the method on full-size filters

Tested used filters from a local building in Minneapolis as a final check on the method



Used prefilter



Used final bag filter

Main Portion of Study

- Minneapolis
  - Selected building and identified personnel to assist with project
  - Selected 4 AHUs, 3 with mixed air (A01, A04, B01) and 1 with 100% outdoor air (S23)
  - Set schedule for filter changeout and shipping to U of M laboratory
  - Requested data from building management system
- Seattle
  - Selected building and identified personnel to assist with project
  - Selected 4 AHUs, all 4 had mixed air capability
  - Set schedule for filter changeout and shipping to U of M laboratory
  - Requested data from building management system

Filters removed and tested

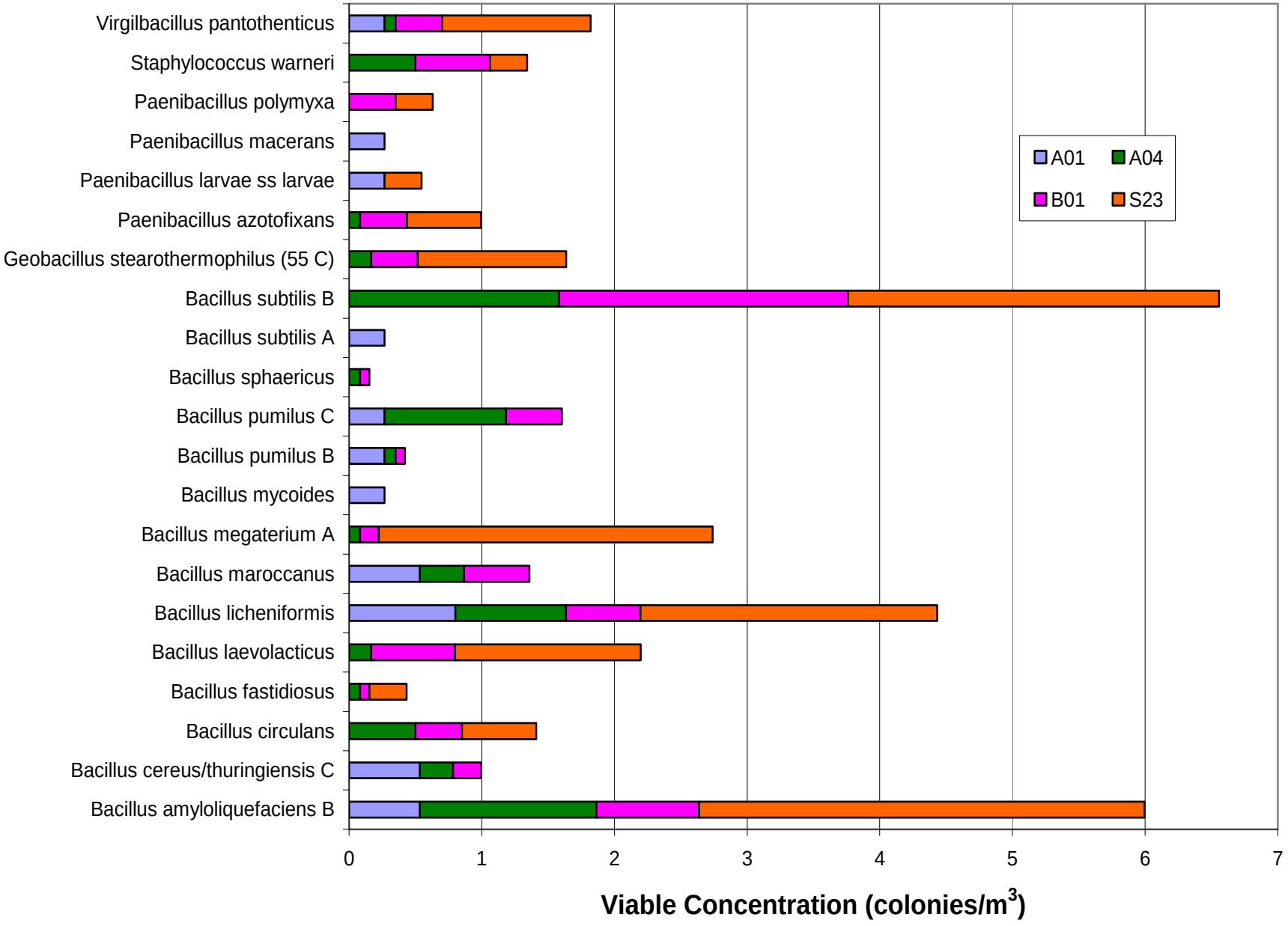
- Minneapolis
  - 1 set final filters
    - 8/1-11/1
  - 3 sets of prefilters
    - 8/1-9/15
    - 9/16 – 11/1
    - 11/1-12/14
- Seattle
  - 1 set of final filters
    - 9/14-12/14
  - 1 set of prefilters
    - 9/14-12/14

Culturable Bacteria Results

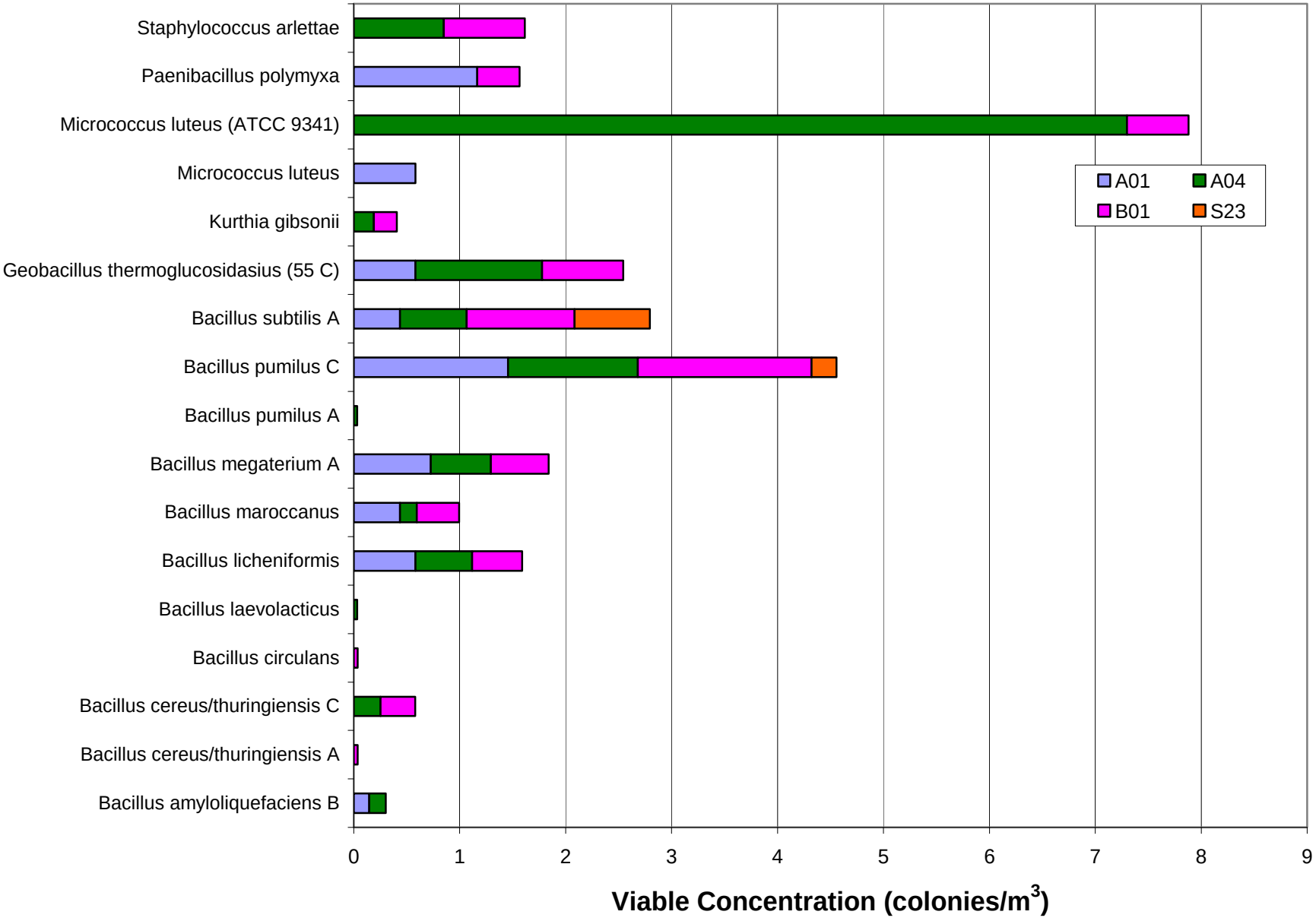
Summary of culturable bacteria identified

Minneapolis & Seattle (20)	Minneapolis (19)	Seattle (5)
Bacillus amyloliquefaciens B	Bacillus badius	Dermacoccus nishinomiyaensis
Bacillus cereus/thuringiensis A ^	Bacillus fastidiosus	Macrococcus caseolyticus
Bacillus cereus/thuringiensis C ^	Bacillus halodurans	Paenibacillus popilliae
Bacillus circulans	Bacillus pumilus B	Paenibacillus validus
Bacillus laevolacticus	Bacillus racemilacticus	Tsukamurella inchonensis
Bacillus licheniformis	Brevibacterium otitidis	
Bacillus maroccanus	Curtobacterium flaccumfaciens	
Bacillus megaterium A	Deinococcus radiopugnans	
Bacillus mycoides #	Kurthia gibsonii	Possible sources
Bacillus pumilus A	Microbacterium laevaniformans	
Bacillus pumilus C	Micrococcus luteus (ATCC 9341)	* human skin
Bacillus sphaericus	Paenibacillus azotofixans	
Bacillus subtilis A	Paenibacillus macerans	# potted plants
Bacillus subtilis B	Paenibacillus pabuli	
Brevibacillus brevis	Staphylococcus arlettae	^ food
Geobacillus stearothermophilus (55C)	Staphylococcus epidermidis *	
Geobacillus thermoglucosidasius (55 C)	Staphylococcus hominis	
Micrococcus luteus *^	Staphylococcus warneri	
Paenibacillus larvae ss larvae	Virgilbacillus pantothenticus	
Paenibacillus polymyxa		

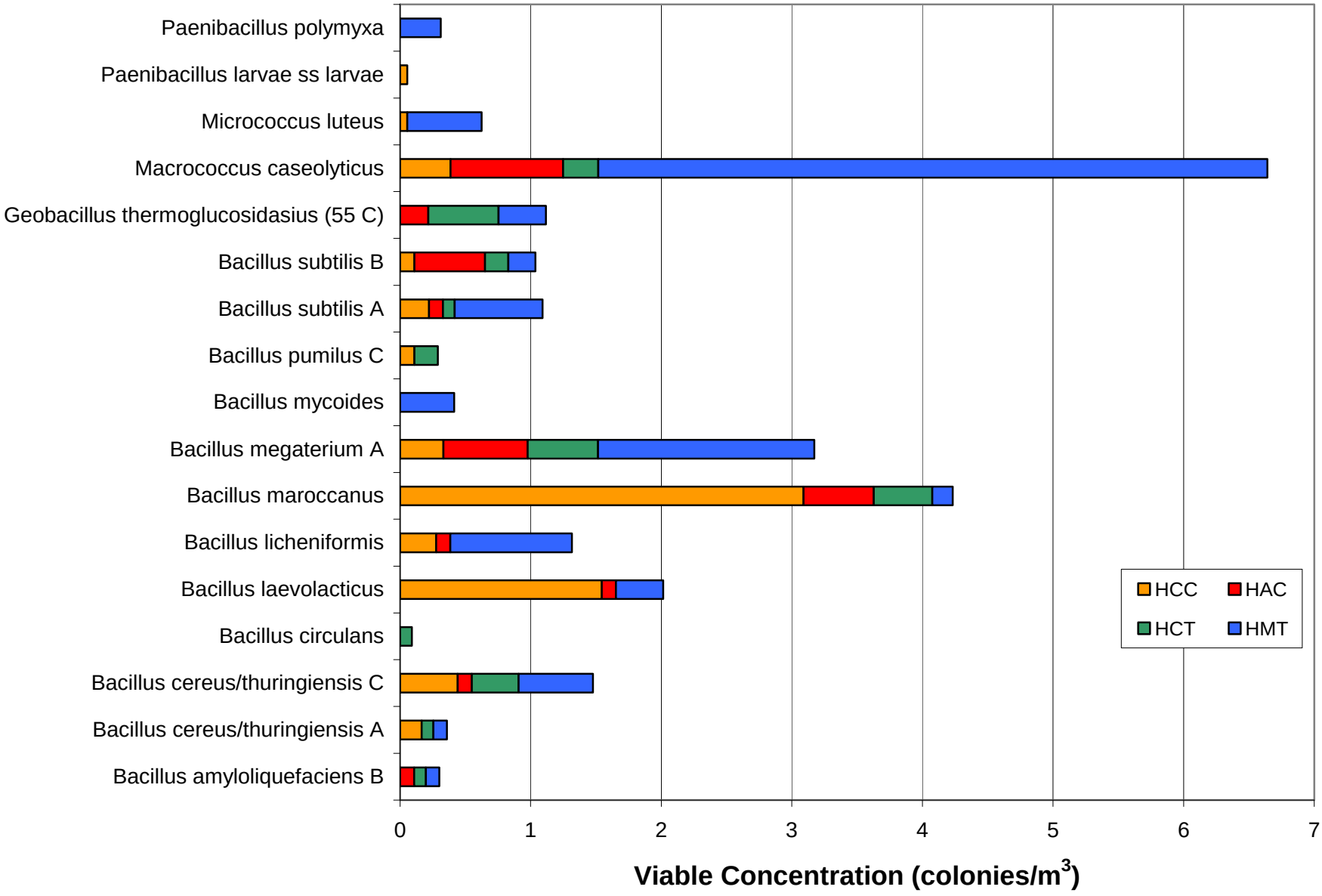
Minneapolis prefilters late summer; 8/1-9/15/05



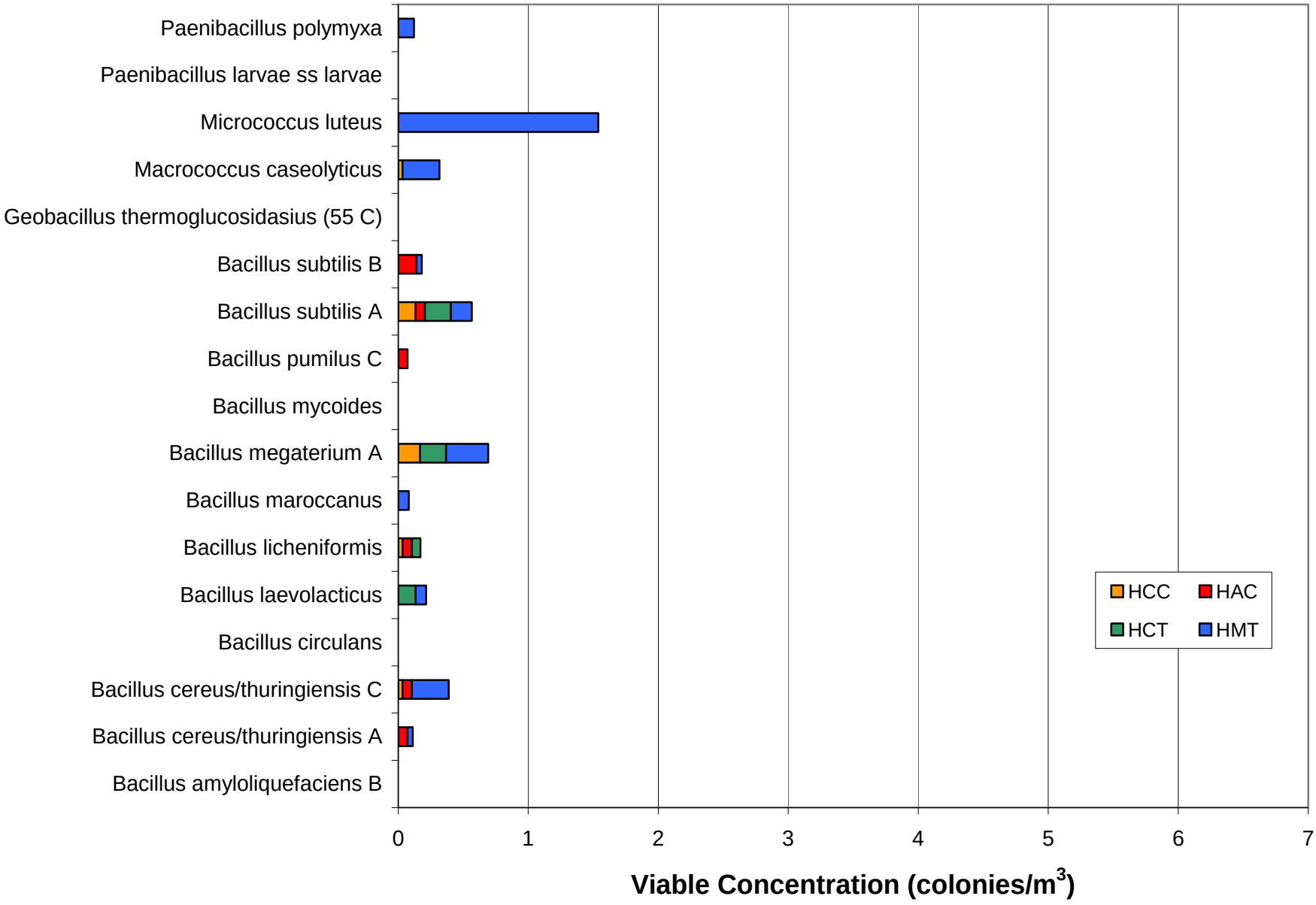
Minneapolis prefilters early winter; 11/1-12/14/05



Seattle prefilters autumn; 9/14-12/14/05



Seattle final filters autumn; 9/14-12/14/05



Targeted bacteria identified

- Klebsiella pneumoniae
- Legionella pneumophila
- Micrococcus luteus
- Pseudomonas aeruginosa

Virus Results

No live viruses found, however some targeted viruses were identified

- Minneapolis
  - Influenza A found in all 3 mixed air AHUs, not found in outside air
  - Influenza B found in outside air
  - Parainfluenza 1 virus found in one of the mixed air AHUs
- Seattle
  - Influenza A found in 2 of the AHUs
  - Influenza B found in a third AHU

Conclusions

- Ventilation filters can be used as bioaerosol samplers for culturable bacteria and the presence of both bacteria and viruses in the air stream using molecular methods (PCR and RT-PCR)
- Prefilters provide much richer data than the final filters in the buildings we studied
- Culturable bacteria species and quantity change with geographical location

Conclusions Cont.

- Concentration of culturable bacteria is not strongly dependent on environmental conditions at the filter
- Evidence of indoor sources for some bacteria
- No live viruses found
- Selected threat agent bacteria and viruses and near neighbors were detected in some of the filters using PCR and RT-PCR methods

Future Work

- Data needed on the fate of culturable bacteria particles once captured by a filter including:
  - ease of removal
  - loss of culturability or viability with time due to desiccation, temperature shifts, and air flow
  - potential growth on loaded filters when sufficient nutrients and conditions favorable to growth occur

Future Work Cont.

- Work needed on virus aerosols
  - more reliable aerosol generation systems
  - quantification of loss mechanisms (generation, airborne state, capture by filter, elution, recovery from aerosol form)
  - better understanding of natural virus aerosol size distributions, concentrations, and viability

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Our Research Team

L to R: Jim Farnsworth, M.A. Ramakrishnan, Seung Won Kim, Senthilvelan Anatharaman, Nick Stanley, Weihua Tang, Professor Peter Raynor, Professor Sagar Goyal, Professor Thomas Kuehn