Novel Methods of Capturing Airborne Contamination and Inactivating Airborne Pathogens

Clinical and Experimental Evidence

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Objectives

- Indoor Air-Pollution and Disease
- Hospital-Acquired Infection
- Existing Air-Cleansing Technology
- Airborne Particle Movement and Capture
- Novel Technical Approaches
- Laboratory and Hospital Experiments
- Summary and Conclusion
Indoor Air-Pollution > Outdoor Air Pollution
90% Population Spend > 90% Time Indoors
Innovation in Air-Cleansing Methods Limited
HEPA Filtration -- Ancient Standard
Particle Control > Traditional Filtering
Particle Control Prevents Infection
Reasons for Concern: Mean Diameters of “Small Particles”

![Diagram showing mean diameters of various infectious agents]

- Whooping Cough: 0.25µ
- Cold Virus: 0.08µ
- Influenza: 0.098µ
- H1N1: 0.22µ
- Measles: 0.12µ
- Pneumonia: 0.707µ
- Staphylococcus: 0.95µ
- Anthrax: 1.12µ
- Typhoid Fever: 1.5µ
- Tuberculosis: 0.637µ
- Smallpox: 0.22µ
- Meningitis: 0.8µ

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Bacteria — — — Viruses
Particulate Air Pollution & Atherosclerosis

- Atherosclerosis -- Lipid and Fibrous plaque
- Airborne Fine Particulate Matter (PM2.5) promotes Atherosclerosis
- Particulate Matter (PM2.5) Mediated Atherosclerosis
  - Pro-oxidant mechanisms
  - Pro-inflammatory mechanisms
  - Multiple cell types
  - Multiple organs
  - Molecular mediators

Biochem Biophys ACTA, 2014
The Terrifying Truth About Air Pollution & Dementia
Cognitive Function and Office Air Quality

- Conventional (Normal IAQ) High VOC vs. Green (Conventional Office) Low VOC vs. Green+ (Green Building) + High Outdoor Air Ventilation Rate
- 61% and 101% Improved for Green and Green+
Epidemic of Alzheimer’s Disease

AMERICANS 65 AND OVER
Living with Alzheimer’s

2015: 5,100,000
2050: 13,500,000 (PROJECTED)

Source: Changing the Trajectory of Alzheimer’s Disease: How a Treatment by 2025 Saves Lives and Dollars, Alzheimer’s Association, 2015

Harvard Gazette, April 4, 2017
Pathophysiology of Alzheimer’s Disease

Plotting the demise of Alzheimer's
Nature vs Nurture
Nature vs Nurture

Environmental Air Exposure
APOE Genetic Alleles & Alzheimer’s Disease

- APOE$_2$ -- APOE$_3$ – APOE$_4$
- APOE$_2$ – Rare, Protective against Alzheimer’s
- APOE$_3$ – Common, Does not influence risk
- APOE$_4$ – 20%, Increases risk, Lowers onset age
- APOE$_4$ – 1 Copy 2-3x Risk, 2 Copies 12x Risk
- Structure correctors – Drugs Aim to Modify APOE$_4$ to be more APOE$_2$ like
Particulate Air Pollutants & Alzheimer’s Disease

- Neurodegenerative effects of ambient particulate air
- Women’s Health Initiative Memory Study (WHIMS)
- Reside - PM > EPA standards Increased Alzheimer’s Disease by 81-92% (Even Greater in APOE4 Carriers)
Particulate Air Pollutants & Alzheimer’s Disease

Original Article

Particulate air pollutants, APOE alleles and their contributions to cognitive impairment in older women and to amyloidogenesis in experimental models

M Cacciottolo1, X Wang2, I Driscoll2, N Woodward1, A Saffan1, J Reyes1, ML Serre2, W Vizuete2, C Sioutas3, TE Morgan4, M Gatz5, HC Chui6, SA Shumaker2, SM Resnick1, MA Espeland1, CE Finch7, and JC Chen7

- Experimental Mouse Models
- 225 hour exposure to urban nanosized PM (nPM)
- Over 15 week period
- Increased Beta-amyloid, increased with APOE4
- Selective atrophy of hippocampal CA 1 neurites
- Increased pro-amyloidogenic processing amyloid precursor protein (APP)
Smoking (Particulate Air Pollution): Responsible for 14% of Dementia

World Health Organization 2015
Particulate Air Pollution (Like Tobacco): There is No Safe Threshold

- Epidemiological studies on large populations have not identified a threshold below which ambient Particulate Matter has no effect on health.
- Within large human populations, there is a wide range in susceptibility such that some subjects are at risk even at the lowest concentrations of PM

*World Health Organization 2015*
Hospital Acquired Infection
$10 Billion Annually

- Viral, Bacterial, & Fungal Pathogens
- Bloodstream Infection
- Pneumonia ($3 Billion)
- Urinary Tract Infection
- Surgical Site Infection
- 2 Million Patients Annually
- 75,000 Deaths Annually

Kowalski and WHO, 2006
Most Dangerous Hospital Acquired Pathogens

- Airborne Spread
- Methicillin Resistant Staphylococcus aureus (MRSA)
- Acinetobactor & Pseudomonas
- Superbugs invincible to standard drug treatment
- Airborne disease transmission rising

“The science of controlling infections caused by airborne microorganisms is a complex mixture of engineering, particle physics, microbiology, and medicine. The rates at which particles settle are a function of their size, shape, density and of course, air movement. Turbulence within a room increases the residence time of larger particles in the air, hence the desire for laminar airflows in operating rooms. Particles or aerosols below about 1 um in size are virtually unaffected by gravity and stay in suspension because of Brownian motion.

Aerosols generated by coughs and sneezes generally affect other persons “only” within 3 to 6 ft. (0.9 to 1.8m). It is virtually impossible for HVAC systems to exert control at this close exposure; therefore, transfer must be controlled using personnel protection and or isolation.”

*MIT Research Suggests that Cough and Sneeze Aerosols can actually travel up to 200 feet!*
Mitigating Airborne Pathogens

- Dilution
- Filtration
- Pressurization
- Disinfection
- UV-C
- Upper Air/Room
Conventional Methods of Air Filtration in Healthcare and Cleanrooms

Conventional Air Filtration Methods
- PRE and High Efficiency Filters (MERV 14 (85%), MERV 15 (95%), HEPA, ULPA, etc.)
- Media Filters are extremely important as they provide the capture mechanism for airborne contaminants.
- Media Filters have a Major Flaw.

AHU Pre & Final Filters

All Filtration Media depend upon one fact: “Particles must get to the media!”
Conventional Design in Healthcare and Cleanrooms

- Conventional Standards in Healthcare Design have not produced an effective enough reduction in HAI’s. These design standards include:
  - Higher air change rates (15, 20, 25 ACH)
  - Air Curtains
  - Laminar flow ceilings
  - HEPA Filtration
  - 100% “fresh”/outside air! Is “fresh”/outside air cleaner?
  - How about “solution by dilution?”

- Cleanrooms utilize multiple HEPA filtration banks and high air change rates to achieve “Contamination free spaces”, which people are rarely allowed to enter. (Class 1 Cleanrooms use between 650-900 ACH!)

Particle Control Technology May Disrupt Existing Clean Methods!
Electrical Properties of a Particle

- **Likes Repel**
- **Unlikes Attract**
Particle Behavior of “Critical Size” Airborne Contaminants

1. SecureAire conditions particles to want to come together.

2. SecureAire forces the conditioned particles to collide.

Once together the particles do not separate!
Particle Behavior of “Critical Size” Airborne Contaminants

The ACS is the only Particle Control and Pathogen Inactivation Device Available
Particle Control Dominant Transport Process

- Particles are Conditioned and Charged
- Charged Particles Collide
- Particles Gain Mass are “Net Neutral”
- Particles are Captured
- Captured Particles/Viable Pathogens are Killed By INACTIVATE™ Technology
- Particles Escaping Capture are Conditioned to Remove Additional Critical Contaminants from Treated Spaces
Experimental Approach

Laboratory Based Study
Out-Patient Surgery Center
Hospital Client Feedback
Objective In-Patient Study
Baseline, Drift and Recovery are the Real Time Metrics for Filtration Performance
Particle Control System Performance:
- Reduced Particle Baseline and Drift by 98.7%
- Reduces the Baseline to its lowest level
- Reduces/Eliminates Recovery Time and Drift
Particle Control Technology Results

AQM Counts at 0.4 μm/Ft³

Same Time of Day | Small Counts (0.4 microns)
--- | ---
Average 6-12-13 | 319010
Average 6-13-13 | 76131
% Improvement | 76

Cleanup Rate = 76%

Reduction of Particles by Particle Control Technology Following HEPA Filtration
Particle Control Technology Operating Room Results

**Operating Room OR-3**
(Pre Filter/Merv 14/HEPA)

**Operating Room P-4**
(Pre Filter/SecureAireM15)

**Particle Difference = 96%**

Average = 93,351

Average = 3,820

Reduction of Airborne Contaminants by Particle Control Technology

SecureAire Confidential
INACTIVATE™ Technology

University of Colorado at Boulder
College of Engineering and Applied Science

INACTIVATETM Technology
Viable Pathogens captured in the Filter Media are Inactivated/Killed by SecureAire’s INACTIVATE Technology:

- The Ion field generated by the PCU causes oxidative stress on the pathogen.
- The High Voltage Charge Density that exists throughout the Collector media.
- “Kill” Testing Results performed on Bacillus subtilis (Anthrax Surrogate)

Figure 2. Standard heterotrophic plate counts of Bacillus subtilis cells recovered from filter surfaces following 3 hr static electric field exposure at 24 °C and 40% RH (replicate 1 ■; replicate 2 □).

DISCUSSION: Exposure to electric field under these conditions caused a significant drop in the recovery of B. subtilis cells from the filter media coupons installed in these pilot units. As judged by elution and standard plating, exposure in the SECUREAIRE platform reduced total cell numbers between 90% and 99% in three hours. When controlled for aging and desiccation effects, the application of a weak electric field across SECUREAIRE fiber filter media hosting otherwise healthy Bacillus subtilis cells appeared to cause damage to these cells such that they could not be could no longer be recognized as microbiological agents by direct microscopic analyses or eluted from filter media.


Viable Airborne Pathogen Trapped in the ACS Are Inactivated
Particle Control Technology Reduces Hospital Acquired Infection

Lake Tahoe Surgical Center Data

Zero Hospital Acquired Infections (HAI) since PCT installation in January 2006.

Lake Tahoe Surgery Center

Particles

TVOCs
Experimental Design
Baseline Data (January 17-25, 2017)

Particles at 0.4u and Larger/Ft³

Average @ 0.4u and Larger

167,408/Ft³

Pink Columns = Surgery times.

Baseline Data (January 17-25, 2017)
SecureAire Technology Deployed (February 13-17, 2017)

Particles at 0.4u and Larger/Ft³

Average @ 0.4u and Larger

9,313/Ft³

Pink Columns = Surgery times.
Particles at 0.4\(\mu\) and Larger/\(\text{ft}^3\)

SecureAire Technology Removed (February 20-24, 2017)

Average @ 0.4\(\mu\) and Larger

33,936/\(\text{ft}^3\)

Pink Columns = Surgery times.
## Particle Control Technology Data Summary:

<table>
<thead>
<tr>
<th>Item</th>
<th>Baseline Data</th>
<th>SecureAire Deployed</th>
<th>SecureAire Removed</th>
<th>Improvement (%)</th>
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</thead>
<tbody>
<tr>
<td>Average Counts (0.4u and larger/Ft3)</td>
<td>167,408</td>
<td>9,313</td>
<td>33,936</td>
<td>94.4</td>
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<tr>
<td>Peak Counts</td>
<td>629,100</td>
<td>22,600</td>
<td>362,300</td>
<td>96.4</td>
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<tr>
<td>Low Counts</td>
<td>4,827</td>
<td>700</td>
<td>1,200</td>
<td>85.4</td>
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<tr>
<td>Surgeries</td>
<td>19</td>
<td>12</td>
<td>12</td>
<td></td>
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<tr>
<td>Hours</td>
<td>30:03</td>
<td>24:06</td>
<td>22:97</td>
<td></td>
</tr>
<tr>
<td>Pathogen Kill Rate</td>
<td>0%</td>
<td>99+%</td>
<td>0%</td>
<td></td>
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</tbody>
</table>
Particle Control Technology Benefits

✓ IAQ Benefits
  ✓ MERV 13 or MERV 15 ASHRAE 52.2
  ✓ INACTIVATE Technology for Airborne Pathogens
  ✓ Lower Rate of Hospital Acquired Infections
  ✓ Increased Rate of Disease Recovery

✓ Particle Control Technology
  ✓ Airborne Contaminants are Effectively Removed
    • TVOC’s
    • Carbon Monoxide/Dioxide
    • Smoke
    • Odors
    • Dissolved Gases
Summary and Conclusions

• Acute and/or Chronic Airborne Particulate Exposure *Causes or Contributes* to Healthcare Acquired Infections, Atherosclerosis, Declining Cognitive Function, and Degenerative Diseases such as Alzheimer’s Disease and Dementia

• Conventional Methods of Filtration lack the ability to Transfer the Contaminant for Capture (A Critical Aspect of Performance)

• Particle Control Science and Technology Provides the Ability to Reduce Critical Airborne Contamination and can be Measured and Verified

• Reducing Airborne Contamination can Reduce Healthcare Acquired Infections

• Particle Control and Inactivate Technology (ACS) is Superior in Conventional Filtration

• Broad Deployment of SecureAire’s PCT and INACTIVATE Technology Could
  • Significantly Improve Clinical Outcomes in Hospitals
  • Reduce the $9.8 Billion Annual Cost of Hospital Acquired Infections
  • Improve Cognitive Function at Home and Office
  • Reduce Inflammatory and Degenerative Disease
Thank You

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