THE AIRBORNE SPREAD OF INFECTIOUS AGENTS: SURVIVAL AND DECONTAMINATION OF HUMAN PATHOGENS IN INDOOR AIR

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May 18, 2017
ACKNOWLEDGEMENTS

- MR. PAUL WEBBER (WEBBER TRAINING)
- DR. KATHIE WRIGHT (BMI, UNIV. OF OTTAWA)
- DR. BAHRAM ZARGAR, (CREMCO)
- MR. RICHARD KIBBEE (CARLETON UNIV., OTTAWA, ON)
- MR. JOSEPH RUBINO, DR. M. KHALID IJAZ & MISS ILZE BRUNING (RB, MONTVALE, NJ)
- DR. M. SOLTANI (JOHNS HOPKINS UNIV., BALTIMORE, MD)
- MR. F.M. KASHKOOLI & MR. F. MORADI (K.N. TOOSI UNIV., TEHRAN)
OBJECTIVES

- ‘AEROBIOLOGY’ & POTENTIAL OF PATHOGEN SPREAD BY AIR
- CHALLENGES OF STUDYING PATHOGENS IN AIR
- OBSTACLES IN LINKING AIR TO ACQUISITION OF INFECTIONS
- SET-UP TO STUDY AIRBORNE SURVIVAL & REMOVAL/INACTIVATION
- TESTING OF AIR DECONTAMINATION DEVICES
- FUTURE DIRECTIONS

SATTAR – TELECLASS ON INDOOR AIR-MAY 18-2017
AERIOBIOLOGY & INDOOR AIR QUALITY

‘AERIOBIOLOGY’ – STUDY OF LIVING ORGANISMS & THEIR PARTS IN AIR

- INCLUDES MICROBIAL QUALITY OF INDOOR AIR

INDOOR AIR IS AN ENVIRONMENTAL EQUALIZER!

EXPOSURE TO ‘INDOOR AIR’ WITH CAVE-DWELLING ~200,000 YEARS AGO

DOMESTICATED ANIMALS (CATTLE, DOGS & PIGS) FACILITATED RISE OF ZOONOSES INCLUDING AIRBORNE ONES (E.G., MEASLES)

WE SPEND MORE TIME INDOORS & BREATHE ~11,000 L OF AIR/DAY

WE ALL LEAVE OUR OWN PERSONAL MICROBIAL ‘FOOTPRINT’ INDOORS

BUT, LACK OF STANDARDIZED WAYS TO STUDY MICROBIAL AIR QUALITY

ALSO, DEARTH OF MEANS TO ASSESS INDOOR AIR DECONTAMINATION

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COMPONENTS OF AEROBIOLOGY

- HUMAN PATHOGENS
- ANIMAL PATHOGENS
- SEEDS
- SMALL INSECTS
- ALLERGENS
- PLANT PATHOGENS
- ALGAE
- POLLEN

AEROBIOLOGY
SOURCES OF AIRBORNE PATHOGENS & ALLERGENS INDOORS (IJAZ ET AL., 2016)
FACTORS AFFECTING INDOOR AIR QUALITY

**CHEMICAL**
- GASES (CO, CO₂, O₃, NO)
- VOLATILE ORGANIC CHEMICALS (PERFUMES, CLEANERS, DISINFECTANTS, PAINTS, PESTICIDES, OFF-GASES)
- ASBESTOS

**BIOLOGICAL**
- HUMANS
- PET ANIMALS (CATS, DOGS, BIRDS)
- VERMIN (MICE, COCKROACHES)
- HOUSE PLANTS
- MICROBES (FREE-FLOATING, BIOFILM-BASED, MYCOTOXINS)
- POLLEN & ALLERGENS (ANIMAL DANDER, DUST MITES)

**PHYSICAL**
- RADON
- PARTICULATES (CIGARETTE SMOKE, PRINTERS/COPIERS)
- SMOKE FROM COOKING & HEATING FUELS
- DUST

**ENVIRONMENTAL**
- OUTDOORS (WEATHER & CLIMATE)
- HVAC SYSTEM
- LIFE-STYLE (AIR TEMP., RH, OCCUPANT TYPE & DENSITY)
INHALED DROPLET NUCLEI (≤5 μm IN DIAM.) REACHING ALVEOLAR SPACES

RETENTION OF INHALED PARTICLES IN TONSILLAR REGION; SUBSEQUENT TRANSLOCATION TO GUT

TRANSFER OF DRIED AIRBORNE CONTAMINATION ON ENVIRONMENTAL SURFACES TO HANDS AND OTHER VEHICLES

REAEROSOLIZATION OF DRIED AIRBORNE CONTAMINATION OF ENVIRONMENTAL SURFACES

SUSCEPTIBLE HOST
### CHALLENGES IN STUDYING AEROBIOLOGY OF PATHOGENS (SATTAR ET AL., 2016)

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<td>CHALLENGE-MICROBE SELECTION</td>
<td>REPRESENTATIVE OF AIRBORNE PATHOGENS, EASE OF CULTURE &amp; RECOVERY, STABILITY DURING AEROSOLIZATION &amp; IN AIR, PREP, CONC., PROTECTION</td>
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<td>SUSPENSION TO BE NEBULIZED</td>
<td>SAFE &amp; STANDARDIZED SOIL LOAD REPRESENTING BODY FLUIDS, ANTI-FOAM, PHYSICAL TRACER (IF NEEDED)</td>
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<td>NEBULIZATION &amp; PARTICLE SIZE DISTRIBUTION</td>
<td>SAFETY FOR MICROBE, GENERATION OF AEROSOLS/DROPLET NUCLEI, GRANULOMETRICS, UNIFORM DISTRIBUTION</td>
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<td>AGING &amp; EXPOSURE CONDITIONS</td>
<td>BETTER CONTROL OF AIR TEMP. &amp; RH; TESTING AT RH BELOW 20%; HARMONIZED FOR MAJOR MICROBIAL TYPES</td>
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<td>AEROSOL COLLECTION &amp; SIZING</td>
<td>PROTECTION OF VIABILITY, OPTIMAL GROWTH CONDITIONS, NEUTRALIZATION OF ACTIVES,</td>
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<td>ASSESSING DECONTAMINATION</td>
<td>PROPER CONTROLS, REALISTIC EFFICACY CRITERIA FOR METHOD/DEVICE AIR-DECONTAMINATION TECHNOLOGIES, NUMBER OF REPEATS</td>
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<td>INTERPRETATION OF DATA</td>
<td>STATISTICAL ANALYSES, FIELD RELEVANCE &amp; REGULATORY REQUIREMENTS</td>
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AEROBIOLOGY CHAMBER TO STUDY MICROBIAL SURVIVAL & DECONTAMINATION IN INDOOR AIR (IJAZ ET AL., 2016)
TEST MICROBE AEROSOLIZED WITH A COLLISON NEBULIZER & TWO-MINUTE AIR SAMPLES COLLECTED WITH A SLIT-TO-AGAR SAMPLER OVER EIGHT HOURS

\[ A. \text{ BAUMANNII} (y = -0.0064x + 4.6558; R^2 = 0.9992) \]

\[ S. \text{ AUREUS} (y = -0.0244x + 4.423; R^2 = 0.9988) \]

\[ K. \text{ PNEUMONIAE} (y = -0.0037x + 4.6773; R^2 = 0.9875) \]

TESTING IN THE AEROBIOLOGY CHAMBER;
AIR TEMP. 22±2°C; RELATIVE HUMIDITY = 50±2%
CHALLENGE MICROBE - *STAPHYLOCOCCUS AUREUS*

ALL DEVICES BASED ON HEPA FILTRATION & UV LIGHT BUT WITH DIFFERENT AIR EXCHANGE RATES
AIR DECONTAMINATION UPON REPEATED MICROBIAL CHALLENGE (ZARGAR ET AL., 2016)

1st nebulized microbial challenge

2nd nebulized microbial challenge

3rd nebulized microbial challenge

log_{10} cfu/m^3

Time (minutes)

S. aureus transformed-biological decay-control

Efficacy test Device #1

based on device baseline-test data to determine LR values post-test
DOES IN-CAR AIR POSE A RISK TO HUMAN HEALTH? (SATTAR ET AL., 2016)

- WORLD TOTAL OF PASSENGER CARS TO INCREASE FROM CURRENT ONE BILLION TO >2.5 BILLION BY 2050; FAMILY CARS REPRESENT ~74% OF WORLD’S YEARLY OUTPUT OF MOTORIZED VEHICLES.

- ~80% OF N. AMERICAN COMMUTERS USE THEIR OWN CAR WITH ANOTHER 5.6% TRAVELLING AS PASSENGERS.

- WITH A LIFE-EXPECTANCY OF ~79 YEARS, THE AVERAGE N. AMERICAN SPENDS 4.3 YEARS DRIVING A CAR!

- THIS EQUATES TO DRIVING ~100 MINUTES/DAY WITH A LIFE-TIME DRIVING DISTANCE OF NEARLY 1.3 MILLION KM INSIDE THE CONFINED & OFTEN SHARED SPACE OF THE CAR.

- EXPOSURE TO A MIX OF POTENTIALLY HARMFUL POLLUTANTS.
### RISK FACTORS FOR IN-CAR SPREAD OF PATHOGENS

(SATTAR ET AL., 2016)

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<th>FACTORS</th>
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<td>LENGTH OF COMMUTE</td>
<td>RISK OF EXPOSURE TO HARMFUL AIRBORNE CONTAMINANTS INCREASES IN DIRECT PROPORTION TO LENGTH &amp; FREQUENCY OF COMMUTE</td>
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<tr>
<td>CAR-POOLING</td>
<td>RISK OF EXPOSURE TO HARMFUL AIRBORNE CONTAMINANTS INCREASES IN DIRECT PROPORTION TO THE NUMBER OF OCCUPANTS</td>
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<td>IMMUNOSUPPRESSION</td>
<td>INCREASING PROPORTION OF THE IMMUNOSUPPRESSED IN SOCIETY</td>
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<tr>
<td>POTENTIAL HOSTS</td>
<td>WIDE VARIATION IN THE AGE &amp; GENERAL HEALTH STATUS OF OCCUPANTS</td>
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<td>STRESS OF DRIVING</td>
<td>STRESS OF DRIVING MAY LOWER BODY’S GENERAL RESISTANCE MECHANISMS</td>
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<tr>
<td>RESPIRABLE PARTICLES (E.G., PM 2.5)</td>
<td>INHALATION OF SUCH PARTICULATES MAY ENHANCE EXPOSURE &amp; SUSCEPTIBILITY TO INFECTIOUS AGENTS</td>
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<tr>
<td>VOLATILE ORGANIC CHEMICALS (VOCs)</td>
<td>EXPOSURE TO VOCs MAY OCCUR SIMULTANEOUSLY WITH INHALATION OF RESPIRABLE PARTICULATES &amp; MICROBES WITH POTENTIAL NEGATIVE ADDITIVE EFFECTS ON HEALTH</td>
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Sources of microbes, allergens, and endotoxins in in-car air (Sattar et al., 2016)

- Cargo
- Road dust
- Windshield washer fluid
- Air conditioning & heating systems
- Occupants
- Upholstery & carpets
- Pets

Sattar – Teleclass on Indoor Air - May 18-2017
CAR CHAMBER (SATTAR ET AL., APPL. ENVIRON. MICROBIOL., 2017)
TESTING OF THREE IN-CAR AIR DECONTAMINATION DEVICES (SATTAR ET AL., 2017)

ALL DEVICES BASED ON HEPA FILTRATION & UV LIGHT BUT WITH DIFFERENT AIR EXCHANGE RATES

CHALLENGE MICROBE - STAPHYLOCOCCUS AUREUS
SUMMARY OF THE MAIN FINDINGS

- Pathogens indoors come from humans, pets, plants, plumbing, toilets, showerhead, heating/cooling/ventilation systems.

- Vacuuming/mopping/dusting resuspend settled dust.

- *A. Baumannii* more stable than *K. Pneumoniae* in air; potentially a better surrogate for Gram-negatives.

- Devices #1 & #2 reduced test microbes by >3-log_{10} in ~45 minutes.

- Device #1 remained effective after 3 microbial challenges.

- Testing of pathogen survival & decontamination in in-car air.

- Aerobiology protocol approved by U.S. EPA.

- Treating indoor air to prevent environmental surface contamination.

FUTURE DIRECTIONS FOR R&D

- **STUDY OF AEROBIOLOGY OF HUMAN PATHOGENS IS IN ITS INFANCY!**
- **STANDARDIZED TEST FACILITIES, PROTOCOLS & GUIDELINES NEEDED**
- **EFFICIENT WAYS TO DETECT LOW LEVELS OF AIRBORNE PATHOGENS**
- **BETTER FIELD INVESTIGATIONS WITH UNEQUIVOCAL RESULTS**
- **MORE INFORMATION ON HEALTH IMPACT OF VARIOUS LEVELS OF RH/TEMP. ON HUMANS & THEIR SUSCEPTIBILITY TO AIRBORNE PATHOGENS**
- **COMBINED HEALTH IMPACT OF AIRBORNE POLLUTANTS**
- **RELEVANCE OF DATA FROM MOLECULAR STUDIES TO ASSESS RISKS?**
- **BETTER & LONGER-TERM RESEARCH FUNDING**

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FURTHER READING


"CLEAN AIR IS A BASIC REQUIREMENT OF LIFE. THE QUALITY OF AIR INSIDE HOMES, OFFICES, SCHOOLS, DAY CARE CENTRES, PUBLIC BUILDINGS, HEALTH CARE FACILITIES OR OTHER PRIVATE AND PUBLIC BUILDINGS WHERE PEOPLE SPEND A LARGE PART OF THEIR LIFE IS AN ESSENTIAL DETERMINANT OF HEALTHY LIFE AND PEOPLE’S WELL-BEING. ............" - WHO, 2010
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<tr>
<td>May 30, 2017</td>
<td>(European Teleclass) THE GOOD THE BAD AND THE UGLY METHODS FOR BED PAN MANAGEMENT</td>
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<td>Speaker: Gertie van Knippenberg-Gordebeke, International Consultant Infection</td>
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<td>Prevention, The Netherlands</td>
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<td>June 1, 2017</td>
<td>USING UNOFFICIAL SOURCES TO MONITOR OUTBREAKS OF EMERGING INFECTIOUS DISEASES:</td>
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<td>LESSONS FROM PROMED</td>
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<td>Speaker: Prof. Lawrence Madoff, Harvard University Medical School, Editor of</td>
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<td>June 7, 2017</td>
<td>(South Pacific Teleclass) THE IMPACT OF CATHETER ASSOCIATED URINARY TRACT</td>
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<td>June 8, 2017</td>
<td>(FREE Teleclass) ESTABLISHING A NATIONAL IPC PROGRAM ON A SHOESTRING BUDGET</td>
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