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Commentary

Workshop on "The Role of Indoor Air as a Vehicle for Human Pathogens": A Panel Discussion

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The primary objective of this panel discussion was to seek input on the following 3 questions from the speakers at the workshop. Comments and questions were also entertained from the members of the audience.

PANEL DISCUSSION

Question 1: Considering the potential advantages of microbial decontamination of indoor air, what criteria should be used to select a given technology?

Dr C. Duchaine: Technologies of interest will depend on the situation and the point source of microbial contamination, for example, a person coughing in an emergency room, a patient vomiting in a hospital ward, or a student vomiting in a classroom. The intervention of choice must be relevant for the site, for instance, a hospital versus a shopping mall. Portable indoor air decontamination devices may be used in smaller areas, such as classrooms, but devices that would allow global decontamination (eg, at a hospital or a shopping mall) would be more challenging. When possible, routine and continuous air treatment may be better than an on-site intervention.

Dr Y. Li: Technologies that are effective for decontamination of circulating air in different situations would be more desirable. One example is the use of UVGI in air circulation ducts if the potentially generated ozone can be effectively removed to avoid its entry into occupied zones. The technology of choice must be safe when people are present, while also being energy efficient. Further, it must not only be effective, but also scalable to suit the site of use. The results of testing in an aerobiology chamber can be much different than those in a large area, such as a hospital or a large shopping mall, where there are on-going changes in the air quality parameters. The debate continues as to whether indoor air for breathing should be treated in the same fashion as water for drinking.

Dr S.A. Sattar: Yes, it is certainly true that waters for drinking and swimming are routinely decontaminated, but not indoor air in most settings! Titanium dioxide filters in ventilation systems could be very valuable as they can work on an ongoing basis without adding any chemicals to the air. However, in situations of very close contact between 2 people, it is virtually impossible to prevent exposure to airborne pathogens. There is an invention though that claims personal protection against airborne pathogens and other contaminants based on 2 thimble-sized cups with filters to be placed inside the nostrils [http://www.breathecleanerair.org/]. I believe that this device requires independent testing and perhaps additional refinements.

Audience member 1: Much of what is being discussed has been done before using algorithms and flow rates at the UNLV [University of Nevada Las Vegas] with the U.S. EPA [Environmental Protection Agency] data. A peer review team consisted of NASA [National Aeronautics and Space Administration] and the EPA radon/asbestos particulate team. There is a rich body of data from the IEST [Institute of Environmental Sciences and Technology, Arlington, IL] on clean room standards and aerospace standards that you should be reviewing. For the space industry, particle exposure testing was performed using microbeads as surrogates. Airflow could be studied without the issue of contamination/decontamination of the chamber. The mass and shape of material contaminants can affect results and the decisions made. Did you consider this? Solutions can be found in other disciplines, and many materials do not require monitoring.

Dr Sattar: It is unfortunate that this original work is not more readily accessible. The 2012 EPA guidelines do not reflect this background information, which could have impacted chamber design.

Audience member 2: Decontamination is too strong of a term unless complete kill is demonstrated. Microbial reduction is a better term.

Dr Sattar: For indoor air quality, you can differentiate between physical removals by filtration versus killing. Decontamination captures both physical removal and killing of microorganisms. Reduction also could be used to describe the situation.

Audience member 2: In real life, it is very difficult to decontaminate a room completely, as microorganisms will be entering continuously through doors, windows, and cracks. Unless the entire building is sealed, there always will be low levels of organisms present.

Dr Sattar: The purpose of air decontamination is not to sterilize the room. The emphasis is on decontaminating the air and not the surfaces. By decreasing the microbial content in the air, you would hope to reduce the contamination present on surfaces as well.

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Although the EPA guideline mentions it, one should avoid the term "sanitization of air" and use "decontamination" instead. "Sanitization" is a nebulous term and is difficult to define. That term is not used in Europe.

Audience member 3: As with any technology, there can be unforeseen consequences, for example, as observed with the high-efficiency plumbing. What are the potential consequences of decontamination of indoor air?

Dr Li: Some microbes are good and some are bad, and the goal should be to remove those organisms that are contaminants in the air. People should not be encouraged to decontaminate ordinary spaces unless known contaminants exist. Air decontamination is important in health care settings, such as for hospital spaces. Overdoing microbial decontamination may have secondary environmental impacts. During the SARS [severe acute respiratory syndrome] outbreak in Hong Kong, significant environmental decontamination and community hygiene measures were associated with a reduction in the reported incidence rates of other respiratory infections during that time.[1] On the other hand, overuse of disinfectants can lead to more pollution in the wastewater.

Dr M.K. Ijaz: No matter what the technology, it has to be safe. In case there are safety concerns to humans, the space being decontaminated should not be occupied during treatment. With regards to opening of doors and re-introduction of microbial contaminants, the data I presented addressed this by showing that a proper indoor air decontamination device can continually deal with ongoing fluctuations in indoor air contamination. No one is suggesting to eliminate all microbes from the air, and, from a practical point of view, it is impossible. The focus is on risk reduction, and a suitable air decontamination device can lower the risk of airborne spread of pathogens.

Dr B. Zargar: One needs to consider the location of the indoor air decontamination device in a given room and also make sure that the existing air-handling system is working properly. Occupants' exposure to potentially harmful bacteria should thus be reduced as much as possible. CFD [computational fluid dynamics] is used widely to simulate the behavior of airborne microorganisms in various settings. To the best of our knowledge, this is the first time that CFD has been used to assess the design and performance of an aerobiology chamber to test the behavior of microorganisms in indoor air. Since the size of airborne particles is an important consideration, we have chosen for our simulation particles in the range of 0.5 to 5 μm in diameter.

Dr Sattar: It is a valid concern not to introduce technologies that will have unforeseen consequences. Good communication is required among engineers, designers, architects, and microbiologists. We are becoming wiser in introducing technologies that are safe and sustainable. Air decontamination goes beyond removing and killing bacteria. Is it conceivable that air decontamination also might remove allergens and pollen in addition to pathogens? Technologies that have a broad base, beyond just microorganisms, might be a more attractive proposition to the consumer.

Audience member 2: If we continually operate the device, we do not know the impact of reduced exposure to pathogens on our immune system. What is the effect of living like this?

Dr Ijaz: Microbial load will be reduced, but contaminants are continually reintroduced. Contamination is minimized, but you do not remove it completely. This is a question of risk reduction.

Audience member 4: What was the size of the chamber you used for testing and modeling of data?

Dr Sattar: Our chamber was built according to the EPA guideline, but was slightly >800 ft^3, or about 24 m^3.

Dr Zargar: The minimum chamber dimensions suggested by the U.S. EPA guidelines are 10 feet × 10 feet × 8 feet (3.048 × 3.048 × 2.44 m).

Audience member 5: One needs to consider the size of the test chamber versus the size of the device. For example, UV [ultraviolet] decontamination is related to energy level, distance, and time. Is it fair to test a device designed to decontaminate a large area and a device meant for a small area in the same sized chamber? Does this give an advantage to the device designed for larger rooms? There are practical concerns with this.

Dr Ijaz: The test chamber built at the University of Ottawa is in accordance with the EPA guideline and is designed as an average-sized room. The chamber is useful for screening technologies. For larger areas, field studies would be required to prove the effectiveness of the technology.

Dr Sattar: Look at HVAC [heating, ventilation, and air conditioning] systems for understanding. The equipment is scaled to the size of the building. It is a matter of engineering rather than the device, and one has to cater to the needs of the home. It is possible that more than one device will be required for decontamination.

Audience member 5: Scale the device to the chamber?

Dr Sattar: Yes.

Dr Ijaz: The research team at the University of Ottawa has already tested a number of different devices. The key question is "how fast and how frequently can the chamber air be processed through the device?" One of the devices produced a 3-log_{10} reduction in experimentally aerosolized bacterial challenge in 45 minutes, while another one required >3 hours to achieve the same level of bacterial reduction. Therefore, the performance of the 2 devices was drastically different.

Audience member 2: The chamber was designed specifically for microbial decontamination of a room, and the EPA provided the size as a standard. You need to know the size of the room you want to decontaminate. Future products would need to be labeled for the size of the room and tested in this size.

Audience member 1: There are many companies active in this area. In the agricultural field, there are ISO [International Organization for Standardization]- and WHO [World Health Organization]-approved protocols for decontaminating facilities such as chicken and egg houses. Construction and other materials in the room may absorb or adsorb the chemicals used to decontaminate the air, and this must be considered. ASHRAE [American Society for Heating, Refrigeration, and Air-Conditioning Engineers] has many standards in this area. There are several guidance documents and standards available in other areas upon which one can draw.

Dr Zargar: The range of airflow can be adjusted for different room sizes, for example, a higher speed for larger rooms and a lower speed for smaller rooms. Instead of building different-sized chambers for testing different devices, mathematical modeling can be used to map the result of experiments in rooms of different sizes.

Audience member 6: Which came first—clean air or fresh air? Is there a standard definition?

Dr Sattar: The EPA standard is a 3 log_{10} reduction in the level of viable bacteria. One needs to know the baseline values to determine if a technology can result in a 3-log_{10} reduction in a specified period of time.

Question 2: What should be the essential elements for an experimental aerobiology facility in terms of the biosafety level and the size and configuration of the test chamber?

Dr J. Mitchell (moderator): This question has been partially answered in the discussion so far.

Dr Sattar: We sought input from the CDC [U.S. Centers for Disease Control and Prevention] as well as from the NIH [U.S. National Institutes of Health]. Based on the feedback, if we aerosolize a biosafety level-2 (BSL-2) organism, then the testing must be conducted in a BSL-3 laboratory. Although we have been using a BSL-3 facility thus

far, our university has recently decided to downgrade that facility to BSL-2 to reduce maintenance and operating costs and to cut down on the paper work for periodic certification as a BSL-3 lab. The decision was based on risk assessment considering that proper staff training and use of personal protective equipment can minimize exposure to the microbes being aerosolized. However, there is still no general consensus on the biosafety containment level needed to work with aerosolized BSL-2 organisms.

Dr Duchaine: If we aerosolize a BSL-2 organism, we use a double-containment strategy so exposure is limited.

Dr Li: It is important to ensure that the chamber is fully mixed so that the organisms are uniformly dispersed and the environmental conditions remain constant. Organism survival is a function of temperature and humidity. Within a chamber that is not uniform, the organism can be dispersed into different environmental conditions. Different-sized chambers are employed for different purposes (eg, VOC [volatile organic compound] release). This is probably reflected in the fact that a typical room or building size does not exist, as different indoor environments are of different sizes.

Question 3: The U.S. EPA guideline (2012) for testing indoor air decontamination technologies recommends the use of specific strains of Staphylococcus aureus *and* Klebsiella pneumoniae *as surrogates for airborne gram-positive and gram-negative vegetative bacterial pathogens, respectively. Are they the most suitable for the purpose? Also, should additional surrogates be considered for other classes of airborne pathogens, such as viruses, fungi, mycobacteria, and spore-forming bacteria? If yes, what desirable attributes should we consider in selecting such surrogates?*

Dr Sattar: This is a crucial aspect where we want to consolidate our views on selection of surrogates. This is not only important for aerobiology but for environmental microbiology as well.

Dr Duchaine: Several types of surrogates will be required, as they all do not behave in the same manner. Eventually, one will need to work with the real contaminating organism to confirm the response. It is important to validate that the surrogate behaves like the actual contaminating organism.

Audience member 3: Dr Alum, in your *Legionella* studies, what was the inoculum level used and does it represent the typical situation that occurs during an outbreak?

Dr Alum: The level of *Legionella* used in the studies was 10 cfu [colony forming units]/m^3. For nonoutbreak–associated cooling towers, we have found, with limited studies, that the *Legionella* numbers were very low, <10 cfu/mL. In cooling tower water associated with outbreaks, the *Legionella* concentration is relatively high.

Audience member 3: In selecting surrogates, do we also need to consider expected numbers present in the targeted situation?

Dr Sattar: Yes, but we always build into the study a certain redundancy and a certain higher level of performance. Hence, the level observed in the actual field situation may not be the level used in testing. The product label has to have assurances built in, so this is the reason we use a higher level of test organisms. It is absolutely right that we need to have surrogates that closely represent those present in air. Consider surrogates in 4 categories: vegetative bacteria, spore-formers, fungi, and viruses. Microalgae are a new area that I cannot comment on yet. If this is a health concern, it should be considered as a fifth category.

Audience member 1: Algae were studied in the 1970s and shown to be an allergen, producing an immune response. Since microalgae exist in the normal environment, I would suggest we keep it on the list as a fifth category.

Audience member 5: There are a lot of data for surface disinfection that suggest a general hierarchy of resistance. Do you see the same hierarchy for aerobiological studies? When norovirus is detected in air from a contaminated area, what is the source? It is less likely from direct breathing, but rather from vomit or fecal aerosolization of norovirus. If norovirus is primarily transmitted by touch, then is it important to decontaminate the air if air transmission does not cause infection?

Dr Duchaine: The source is the patients themselves. The sampling device was present where the actively emitting patients were, and they may have vomited or had diarrhea. There may be up to 10^{12} virus particles per gram of diarrheic feces, and this would be part of the aerosol. Surfaces are cleaned, but if an airborne route exists, this explains how other patients some distance away become infected. One way to prevent spreading of infections is to decontaminate the air. For the first part of your question, droplet nuclei need to come in contact with the product for an appropriate period of time. Unlike surface testing, the air decontaminant contact time is longer.

Audience member 5: How do you compare the resistance levels of the different categories of organisms (bacteria, virus, and fungi) in air?

Dr Sattar: You need to develop comparative data, but one would expect differences in comparing liquid disinfectants to air treatments. For liquid disinfectants, there is a larger volume to infectious agent ratio. In air, the ratio is not the same, and the testing dynamics are different. Therefore, one cannot compare liquid disinfection testing to air decontamination. There is a need to consider surrogate organisms for each of the 5 categories because there are practical and ethical issues to deal with in working with actual pathogens. For example, *M* [*Mycobacterium*] *tuberculosis* can spread by air, but it is a relatively slow-growing pathogen and difficult to obtain in viability titers high enough for aerosolization. Also, how can we grow enough of the SARS virus to contaminate an aerobiology chamber? If regulators allow the use of surrogate organisms for testing environmental surface disinfectants, why can their use not be extended to air testing?

Audience member 7: We should not limit ourselves to key pathogens, such as respiratory, as less known ones can become a problem. Could infection or airflow be modeled through adjoining rooms or halls, rather than in a chamber? That might be beneficial to better align with the real world.

Dr Zargar: Modeling of a furnished chamber can be used as the starting point for simulation of a hospital room. Modeling of the ventilation system in any such setting would be crucial.

Audience member 2: Following up on the hierarchy question, AD [Antimicrobial Division of the U.S. EPA] for registration purposes allowed 60% glycol products to have an air sanitization claim. Data are required to support this, so registrants must provide the data. This testing is in its infancy. As more data become available, a hierarchy for air decontamination can be developed. Selecting surrogates also is still in its infancy and currently is supported by historical selection.

Mr Rubino: It is time to close the session, and I would like to thank ASTM International for supporting this workshop. Special thanks to Dr Sattar, Dr Mitchell, Dr Ijaz, and the rest of the team, as well as to the speakers.

Reference

1. Lo JY, Tsang TH, Leung YH, Yeung EY, Wu T, Lim WW. Respiratory infections during SARS outbreak, Hong Kong, 2003. Emerg Infect Dis 2005;11:1738-41.