AEML, Inc.
Microbiology Laboratories

Episode 671| August 12, 2022 | 12:00 PM EST

William Bahnfleth, PhD, PE
Dustin Poppendieck, PhD
Alison Savage, MPH

Why Indoor Chemistry Matters! Part 2
Partitioning, Transformations and Management of Chemicals in Indoor Environments

This week we welcomed Dr. Bill Bahnfleth, Dr. Dustin Poppendieck and from EPA Alison Savage for part 2 of our series on the NASEM document Why Indoor Chemistry Matters! This week we focused on the Management of Chemicals in Indoor Environments.

William Bahnfleth is a professor of architectural engineering at the Pennsylvania State University (Penn State) in University Park, PA, where he has been employed since 1994. Previously, he was a Senior Consultant for ZBA, Inc. in Cincinnati, OH and a Principal Investigator at the U.S. Army Construction Engineering Research Laboratory in Champaign, IL. He holds BS, MS, and PhD degrees in Mechanical Engineering from the University of Illinois, where he also earned a Bachelor of Music degree in instrumental performance. His is a registered professional engineer. Dr. Bahnfleth's primary research interest is indoor air quality, in particular, control of bioaerosols. He is the author or co-author of more than 180 technical papers and articles and 15 books and book chapters.

Dr. Bahnfleth is a fellow of ASHRAE, the American Society of Mechanical Engineers (ASME) and the International Society for Indoor Air Quality and Climate (ISIAQ). He has served ASHRAE in a variety of capacities, including 2013-14 Society President and as chair of the ASHRAE Epidemic Task Force. His ASHRAE honors include a 1st place ASHRAE Technology Award, Distinguished Service and Exceptional Service Awards, The Louise and Bill Holladay Distinguished Fellow Award, the E.K. Campbell Award of Merit for teaching, the Donald Bahnfleth Environmental Health Award, and the F. Paul Anderson Award ASHRAE's highest individual honor. He is also a recipient of the Penn State Engineering Alumni Society's World-Class Engineering Faculty Award.

Dustin Poppendieck is a environmental engineer at the National Institute of Standards and Technology (NIST). He received his PhD in Civil and Environmental Engineering from the University of Texas at Austin in 2002. He is a fellow of the International Society for Indoor Air Quality and Climate (ISIAQ). Dustin has been investigating indoor air chemistry since 2002. Most of his efforts have involved characterizing primary emission sources and heterogenous reactions at material surfaces. He has investigated emissions from kerosene can lamps used by nearly a billion people throughout the developing world, spray polyurethane foam, non-smoldering cigarette butts and indoor air cleaning devices. In addition, Dustin has studied the disinfection of biologically contaminated building materials (i.e., anthrax) using high concentrations of ozone, chlorine dioxide, hydrogen peroxide and methyl bromide.

Alison Savage, M.P.H., is a Biologist in the Indoor Environments Division (IED) in the Office of Radiation and Indoor Air (ORIA) at the US Environmental Protection Agency (EPA) and is the current team leader of the Scientific Analysis Team. Since joining IED in 2018, she has worked on a wide variety of indoor air quality (IAQ) issues including reducing exposure to wildfire smoke in indoor environments, air cleaning and filtration, indoor chemistry, indoor exposure to particulate matter, and low-cost air sensors for IAQ, as well as IAQ issues related to emergency preparedness, response, and recovery for wildfires and floods. Ms. Savage manages the EPA task order that supported the National Academies of Sciences, Engineering and Medicine (NASEM) Emerging Science on Indoor Chemistry consensus study. She also manages the task order supporting the ongoing NASEM consensus study on the Health Risks of Indoor Exposures to Fine Particulate Matter and Practical Mitigation Solutions. Prior to joining EPA, she served as a Peace Corps volunteer in Peru. She holds an M.P.H. in Global Environmental Health from the Rollins School of Public Health at Emory University and a B.S. in Biology from the University of Michigan.

Nuggets mined from today's show:

Dustin Poppendieck- Dustin's interest in indoor chemistry was piqued when he studied the cleanup effort of the Senate Hart building after it was attacked with anthrax. Researchers knew that when lethal levels of disinfectant were reached in the lab, the disinfectant killed anthrax spores. Dustin studied why lethal levels were not achieved in the Senate Hart building and found that disinfectant was consumed by surfaces preventing lethal disinfectant levels from being attained. When studying methamphetamine mitigation, he found that methamphetamine would migrate through latex paint. He also studied spray polyurethane emissions. He opines that indoor environments are chemical reactors. Building materials and home furnishings can be both sinks and sources. He has also studied cig butts and flame retardants. After touring the Net Zero House, Charlie Weschler contacted Marina Vance and Delphine Farmer to do experiments on: cooking, smoking, cleaning and surface aging at NIST. This resulted in the Chemical Assessment of Surface And Air (CASA) field campaign with 12 universities. Indoor chemistry is very complex.

Alison Savage- When consumer products are used indoors they can create new particles under certain circumstances. EPA recently published info on flooded home cleanup https://www.epa.gov/flooded-homes

Dustin Poppendieck
Partitioning is accounting, keeping track where chemicals are. Using the analogy of keeping track of people at an oceanside beach. Partitioning coefficients are similar to how many people are on the beach compared to how many people are in the water? Partitioning coefficients are not related to time. Temperature, rain and humidity can influence how many people are on the beach and how many people are in the water. Partitioning is both chemical dependent and environmentally dependent. Surfaces affect partitioning, sandy beach versus rocky beach. Capacity is the big picture, how many people on a beach in Florida versus how many people on a beach in Alaska? Chemicals are distributed by air and partition to everything. Chemicals can be in solid, liquid, or gas phase. Partitioning controls how things happen. Partitioning is an equilibrium situation. What is in one material versus another, residues can build up. We want to remove things from the air.

Bill Bahnfleth- Picking up on Dustin's analogy, there are many people on the beach and a few in the water. Sharks may catch a few swimmers in the water, but there are still a lot left on the beach. Using ventilation to remove chemicals that are in much higher concentration on surfaces and in materials is similar. Hazardous chemicals can partition onto surfaces and into solids. Control methods include:

flush chemicals into the air (works well for some, not well for others like SVOCs), clean surfaces or replace materials. 3rd hand smoke from tobacco or fires is an example of a reservoir created by partitioning from the air.

Dustin Poppendieck- There is a wide range of chemical partitioning: SVOCs, PAHs, methamphetamine. Chemical migration may occur at a very low rate. It takes a long time to lower the reservoir. Reservoirs are brought into the home such as carpet cushion, and upholstery foam. Chemical migration from deep within material such as urea formaldehyde foam takes a long time. Recently applied chemicals (smoke event or cooking) migrate much faster from surfaces. Relatively large surface area per unit volume surfaces can be important reservoirs.

Bill Bahnfleth- Surfaces and materials sorb and desorb. Whether contaminants are being removed from air or added to it can depend on temperature and humidity variation.

Dustin Poppendieck- An increase in temperature of 10° C doubles the emission rate. Water vapor can be different: from only a few water molecules layered together to a puddle. The concentration of hydrophilic substances is lower at higher RH. The concentration of hydrophobic substances is higher at higher RH.

Bill Bahnfleth- The effect of air flow on chemical emission rates is similar to the effect of air flow on heat loss. A fan cools skin by increasing heat transfer and the heat transfer at the skin surface goes into the air.

Dustin Poppendieck- Chemical transformation is any process that leads to the loss or removal of something. Multiple baking ingredients go into baking a cookie. Once the cookie is baked the baking process cannot be reversed. However, in a chocolate chip cookie, the chips may be removed and the transformation process reversed.

Bill Bahnfleth- HVAC ductwork have high potential to sorb chemicals in their gas phase. The public often doesn't realize that the products we bring indoors causes chemical processes to occur.

Alison Savage- Certain activities such as cooking, cleaning and increasing ventilation may result in greater potential for indoor chemical transformations by increasing concentrations of certain drivers of indoor chemistry. For example, bringing in more outdoor air increases O_3 levels indoors, by drawing in more O_3.

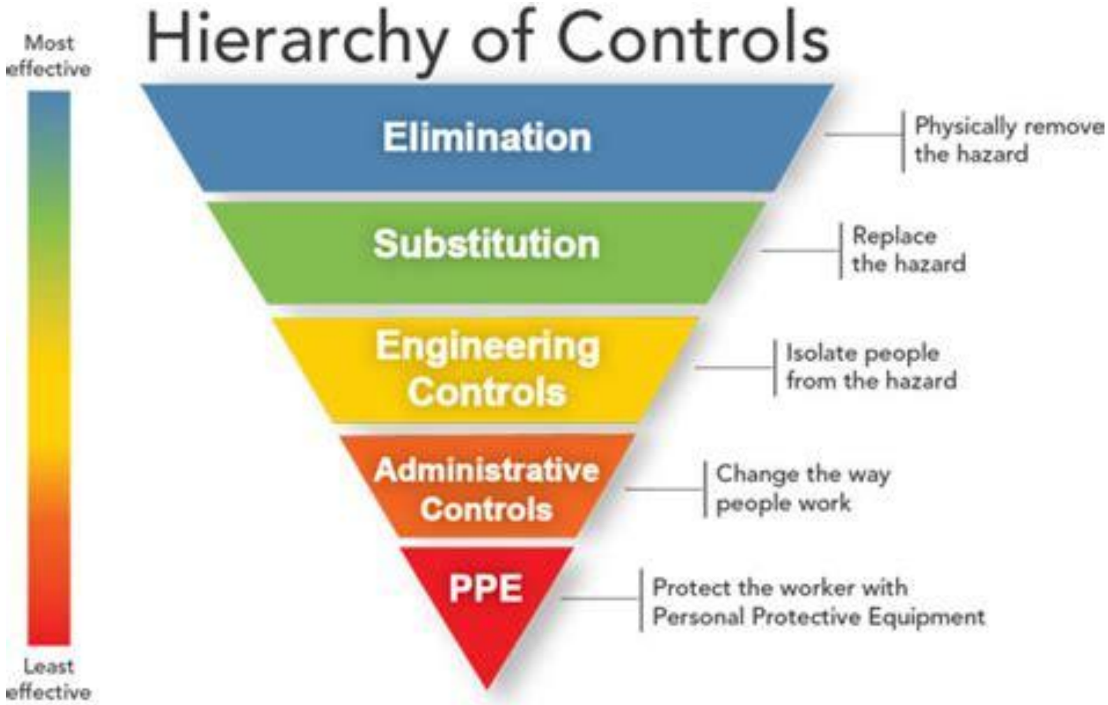
Dustin Poppendieck- We don't know what happens chemically when we use disinfectants indoors.

Managing Odors Indoors:

Where is the odor emitting: surface or airborne?
What are the biggest reservoirs: carpet cushion, upholstery, walls, floors, etc.?
Naturally, ventilation cannot solve all IAQ problems. Sometimes source control is the best method: "If there is a pile of manure in a space, do not try to remove the odor by ventilation. Remove the pile of manure." (Max von Pettenkofer, 1858.)
A viable technique in one place may be irresponsible in another.
ASHRAE has studied reactions between O_3 and human skin oils.

Bill Bahnfleth- We need to consider chronic occupant and worker exposures. Need an actionable definition of indoor air quality – which contaminants to monitor and what levels are acceptable. There could be thousands of chemicals in an indoor environment and we can't track all of them. To get to a manageable number, we need to calculate and rank the risks posed by the most common chemicals at typical exposure levels if we are ever going to solve the problem.

The management of chemical contaminants in indoor environments includes removal (through ventilation, filtration, sorption, physical cleaning, and passive surface removal) and chemical transformations (including photolysis, ionizers, chemical additions, and photocatalysis). No single management approach can remove all contaminants that are present indoors; therefore, source elimination is always the preferred method of control.



Buy safe, certified products that meet industry safety standards.
Furnishings can be both source and sinks.

ROUNDUP
Bill Bahnfleth- Summer Camp
Demonstrated ASHRAE Covid recommendations in meeting room holding 500 people.

- Inspected HVAC system and found fresh air intakes closed, had to tape intakes open.
- Upgraded HVAC filers from MERV 8 to MERV 13, needed to do "filter origami" in order to get filters to fit in racks.
- Built Corsi-Rosenthal cubes
- Installed portable UVC lights
- Measured CO^2 (maximum was about 1200 ppm, indicating OK ventilation per ASHRAE Standard 62.1)

Alison Savage- EPA goals are to ID pollutants of concern and mitigate to protect vulnerable communities and populations. COVID increased the public interest in IEQ. There is a greater interest in IEQ in schools.

Dustin Poppendieck- We spend 90% of our time indoors. So 90% of our chemical exposures are indoors. COVID was the silver lining that raised public awareness of IEQ.
We don't understand what is good and bad indoors.
We don't understand the significance of indoor chemistry as a problem.
We don't have all the answers.
We must communicate the information to vulnerable communities.

Bill Bahnfleth- There is much we don't know. National Academy Committees are researching and working on the problem. However, we already know enough to make indoor environments better. We need to communicate what we know about indoor chemistry to building operators and occupants. Building operators need to know more about indoor chemistry.

Z-Man signing off

References:

Why Indoor Chemistry Matters
https://nap.nationalacademies.org/catalog/26228/why-indoor-chemistry-matters

ASHRAE OR-16-C033
Root Cause of the Odor Generated by Germicidal UV Disinfection with Mobile Units
https://standards.globalspec.com/std/10002024/ASHRAE%20OR-16-C033

Scope:
Germicidal ultraviolet (UV) light has long been used successfully for the disinfection of water, air, and surfaces, and has become a common practice in the healthcare industry. There has been, however, an unresolved health concern with regard to the residual odors that have often been noted after rooms have been disinfected, and no satisfactory explanation of these possible volatile organic compounds (VOCs) has previously been published. This study explains the residual odors in terms of thiol or mercaptan molecules that can be produced by the UV irradiation of keratin and cysteine. Keratin is a protein that is found in skin squames while cysteine is a similar molecule found in hair. They also both contain a significant amount of sulfur. Skin squames and hair particles are common contaminants of indoor environments and are present in airborne dust as well as being surface-borne. UV photons carry sufficient energy to break the chemical bonds of keratin and cysteine, as well as the chemical byproducts including volatile smaller sulfur-containing molecules that fall into the categories of thiols and mercaptans. The human nose is extremely sensitive to these molecules and can detect them at concentrations as low as 1 part per billion. The smell after UV disinfection is sometimes described as that of burning hair or the pungent odor of rotten eggs or garlic. The latter smell is characteristic of mercaptans. In an

indoor environment where the dust loading in the air may typically be about 100 µg/m^3(0.000044 grain/ft^3), the aftermath of the UV disinfection process will leave behind a concentration of mercaptans of about 2 ppb, or twice the smell threshold level. According to the CSST in Quebec and per OSHA, the safe level for 8 hours of exposure to mercaptans is 500 ppb. Consequently, the actual level obtained after UV disinfection is negligible and therefore it is concluded that the VOCs responsible for the residual odor after UV disinfection do not pose a health hazard to humans.

Trivia:

Name the combination of 3 words by which hydroxyl radicals were originally called after their discovery?

Answer: Open Air Factor

Answered by: Jillian Dunbar, Florida Dept. of Health, Tallahassee, FL