Equal Access to Healthy Indoor Air

The objective of this challenge is to develop a holistic solution to address indoor air quality (IAQ) inequities in the United States. This topic relates to both the technical aspects of IAQ as well as other areas including IAQ-related policy, epidemiology, environmental justice, community economic impact, commercialization, codes and standards, and appropriate metrics development.

Background

Poor IAQ in buildings can result from the infiltration of outdoor air pollutants as well as from the generation of air contaminants from indoor sources. Outdoor air pollution can be generated by sources such as power plants and industries, traffic emissions from major highways or roads, and wildfires. Indoor sources include combustion equipment and appliances, installed or stored products and materials (e.g., off-gassing of volatile organic compounds from furniture, cleaning products, and building materials), mold, pests, pets, indoor smoking, radon, legacy building materials like lead and asbestos, etc. The degradation of IAQ is exacerbated by poor ventilation.

Most Americans spend approximately 90% of their time indoors, where air pollutants can be two to five times more concentrated than outdoors.[1] Consequently, prolonged exposure to poor IAQ can lead to respiratory and cardiovascular health problems including respiratory infections, allergies, asthma, chronic obstructive pulmonary disease, bronchitis, sick building syndrome, and lung cancer.[2] Acute exposure (over hours) to air pollutants can cause irritation to the nose, throat, and eyes and aggravate asthma, lung disease, bronchitis, and respiratory disease in susceptible individuals.[3] In addition, poor IAQ may also lead to increased school and work absenteeism and loss of work productivity due to reduced cognitive performance.[4] In extreme cases, serious and life-threatening situations can arise due to poor IAQ. More than 100 people die each year in the U.S. from unintentional exposure to carbon monoxide gas from portable generators and other fuel burning appliances and products.[5] Throughout the United States, radon is the number one cause of lung cancer among non-smokers, and secondhand smoke is the third leading cause of lung cancer, responsible for an estimated 3,000 lung cancer deaths every year.[6]

Prior research has shown that households with lower socioeconomic status encounter greater concentrations of indoor air pollutants based on multiple factors such as age of the house, area of peeling paint, water leaks, neighborhood street noise and traffic density, proximity to factories, presence of rodents, mean floor area, occupant density, presence of cracks in floors and walls, etc.[7] A

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[1] U.S. Environmental Protection Agency. 1987. "The total exposure assessment methodology (TEAM) study: Summary and analysis." EPA/600/6-87/002a. Washington, DC.

[2] Sundell, J. 2004. "On the history of indoor air quality and health." *Indoor Air*, 14(s 7), pp.51-58. DOI: 10.1111/j.1600-0668.2004.00273.x

[3] Manisalidis, I., Stavropoulou, E., Stavropoulos, A. and Bezirtzoglou, E., 2020. Environmental and health impacts of air pollution: a review. Frontiers in public health, 8, p.14. https://doi.org/10.3389/fpubh.2020.00014

[4] Zhang, X., Wargocki, P., Lian, Z. and Thyregod, C., 2017. "Effects of exposure to carbon dioxide and bioeffluents on perceived air quality, self-assessed acute health symptoms, and cognitive performance." *Indoor Air*, 27(1), pp.47-64. https://doi.org/10.1111/ina.12284

5 U.S. Consumer Product Safety Commission, Carbon Monoxide Safety Information for Congressional Offices – Suggested Insert for Constituent Newsletters and E-mails. Available at https://www.cpsc.gov/s3fs-public/pdfs/blk_media_Carbon_Monoxide_Safety_Information_For_Congressional_Offices.pdf (Accessed 8/3/2021).

6 U.S. Environmental Protection Agency. "Health Risk of Radon". Available at: https://www.epa.gov/radon/health-risk-radon#head (Accessed 8/3/2021).

[7] Adamkiewicz et al. 2011. "Moving Environmental Justice Indoors: Understanding Structural Influences on Residential Exposure Patterns in Low-Income Communities." *American Journal of Public Health*, 101(Suppl 1): S238–S245. DOI: 10.2105/AJPH.2011.300119.

study from Peters et al.[8] showed that holes in the wall or ceiling that are found more often in the houses occupied by lower socioeconomic status households were associated with a 6- to 11-fold increase in kitchen cockroach allergen concentrations. The official poverty rate in the United States in 2019 was 10.5% of the total population—approximately 34 million people.[9] A substantial body of literature demonstrates that poor housing conditions, which are often directly associated with socioeconomic status of the household, can contribute to increased infectious disease transmission, injuries, asthma symptoms, lead poisoning, and mental health problems—both directly (e.g., because of environmental hazards) and indirectly (e.g., by contributing to psychosocial stress that exacerbates illness).[10]

Besides socioeconomic status, vulnerability to poor IAQ can depend on several other factors including age of the occupants, density of housing, home ownership status (renter versus homeowner), race, ethnicity, occupation, and infrastructure dependence.[11] The interplay of these multiple factors leading to IAQ inequity will collectively affect the solutions used to address the problem.

Improvements in IAQ could dramatically improve overall human health; however, to be implemented widely, solutions should not add significantly to the building's energy use or to homeowner or renter energy bills. IAQ improvement solutions such as increased ventilation rates in buildings can even reduce the incidence and transmission of respiratory diseases including COVID-19.[12] Due to the multi-faceted impacts of IAQ improvement solutions, technological solutions alone cannot be realized impactfully without taking policy-related, economic, and other nontechnological considerations into account.

Examples of technological solutions for IAQ improvement include the use of portable air purifiers, upgrades to heating, ventilating, and air conditioning filters, kitchen range hoods that vent exhaust outside, heat recovery ventilators, and motion-activated mechanical exhaust fans. However, these solutions may be unaffordable to the economically disadvantaged population. Recent technological developments in indoor environmental sensing, modeling, and control capabilities can be leveraged to potentially optimize for IAQ and energy efficiency and improve the affordability and access of these solutions to a wider population. More innovation is needed to increase the affordability and widen the access of smart or sensor-driven and other recently developed IAQ solutions.

On the other hand, policies provide a basis for generating solutions at a nontechnological level. Examples of a policy-level approach include the health and safety inspections and necessary corrective actions built into the operating procedures of the U.S. Department of Energy (DOE)'s Weatherization Assistance Program (WAP) and the U.S. Department of Housing and Urban Development (HUD) programs, and several other non-federal programs from the states, local governments, and non-profit

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8 Peters, J.L., Levy, J.I., Rogers, C.A., Burge, H.A. and Spengler, J.D., 2007. Determinants of allergen concentrations in apartments of asthmatic children living in public housing. Journal of Urban Health, 84(2), pp.185-197. Available at: https://link.springer.com/content/pdf/10.1007/s11524-006-9146-2.pdf (Accessed 8/3/2021)

9 Semega, J.L., Kollar, M.A., Shrider, E.A., and Creamer, J.F. 2019. "Income and poverty in the United States: 2019." U.S. Census, Current Population Reports, pp.12-20. Available at https://www.census.gov/library/publications/2020/demo/p60-270.html (Accessed 7/1/2021).

10 Saegert, S.C., Klitzman, S., Freudenberg, N., Cooperman-Mroczek, J. and Nassar, S. 2003. Healthy housing: a structured review of published evaluations of US interventions to improve health by modifying housing in the United States, 1990–2001. *American Journal of Public Health*, 93(9), pp.1471-1477. Available at https://ajph.aphapublications.org/doi/full/10.2105/AJPH.93.9.1471.

11 Cutter, S.L., Boruff, B.J. and Shirley, W.L. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly*, 84(2), pp.242-261. Available at https://onlinelibrary.wiley.com/doi/10.1111/1540-6237.8402002 (Accessed 7/22/2021).

12 Morawska, L., Tang, J.W., Bahnfleth, W., Bluyssen, P.M., Boerstra, A., Buonanno, G., Cao, J., Dancer, S., Floto, A., Franchimon, F. and Haworth, C. 2020. How can airborne transmission of COVID-19 indoors be minimised? *Environment International*, 142, p.105832. Available at https://www.sciencedirect.com/science/article/pii/S0160412020317876.

organizations. Pathways are also needed to enhance the delivery of effective and impactful solutions to IAQ inequities to end users in a cost-effective and practical manner.

The Challenge

The JUMP into STEM competition asks teams to investigate holistic solutions and explore impactful factors (such as science, policies, awareness, information technology, codes and standards, and economics) behind inequities in IAQ. Teams must develop a problem statement to address IAQ inequities for a specific stakeholder group and present a holistic response that includes a technical solution or process as well as other components such as policy, awareness, information technology, and economic solutions.

Suggestions for student teams to work on include but are not limited to the following:

- Characterizing indoor air quality to provide better guidance for policy development. (Examples include developing novel metrics related to IAQ based on established scientific findings and the relationship between IAQ and health. Analogous to the outdoor air quality index, such quantitative metrics could then highlight the status quo as well as guide intervention strategies or occupant behaviors for mitigating the harmful effects of indoor air contaminants.)
- Managing IAQ in buildings through targeted sensing and ventilation strategies.
- Focusing on a specific pollutant source, building type, or geographical location.
- Generating or analyzing relevant data through mobile applications, machine learning, and databases that are helpful in making informed decisions at either the building or community level.
- Developing innovative financing mechanisms to upgrade existing buildings with an improved IAQ solution, etc.
- Developing new mechanisms of collaboration between existing programs and agencies that can co-address IAQ issues in tandem with other issues such as energy efficiency. For example, OneTouch program model that connects WAP, Lead hazard abatement, and HUD rehab funded programs through lead sharing in Vermont.[13] WAP, Zero Energy Ready Homes (ZERH), and Home Performance with ENERGY STAR® (HPwES) are some of the existing federal programs funded by DOE that include IAQ as well as energy efficiency elements with respect to buildings.

Students should develop a problem statement and propose a solution related to building or community-scale IAQ issues. Student submissions should:

- Describe the scope and context of the problem based on a real building and/or stakeholder group in the United States
- Identify affected communities, making sure to include socioeconomically vulnerable communities when compared against groups with high socioeconomic status.
- Develop a holistic solution including technical, policy-related, or economic aspects to address the IAQ problems at the building or community scale. At a building scale, solutions may focus on new building designs or existing building retrofits. At a community scale, the solutions may focus on community behavioral patterns, local infrastructures, community awareness, etc.

[13] OneTouch Housing website, Vermont: https://onetouchhousing.com/

- Discuss appropriate and expected impacts and benefits of the proposed solution. This should include a cost/benefit analysis of the proposed solution and should also include noneconomic impacts whenever possible. The noneconomic impacts could include items such as environmental impact, noise level, security challenges, logistical challenges, health risks, safety hazards, workmanship quality, and speed of implementation.
- Develop a plan that describes how the team envisions bringing its idea from concept to a final implementation that is useful to the end user. Examples include a detailed plan to convert the idea to a commercially viable, market-ready product for existing buildings and/or communities; or a roadmap to integrate the idea into a new construction or retrofit project.