ANNOTATED BIBLIOGRAPHY

Beard, John D, Celeste Beck, Randall Graham, Steven C Packham, Monica Traphagan, Rebecca T Giles, and John G Morgan. "Winter Temperature Inversions and Emergency Department Visits for Asthma in Salt Lake County, Utah, 2003—2008." *Environmental Health Perspectives* 120, no. 10 (2012): 1385-390. DOI: 10.1289/ehp.1104349

This article explores the relationship between emergency visits and diagnoses of Asthma during inversion days in Salt Lake City. The scholars used data from the National Weather Service and electronic records of ED visits for asthma throughout the winters of 2003, 2004, 2007, and 2008. The scholars found an association between inversion days and ED visits for asthma but found this association was limited to days with "PM_{10}, maximum temperature, and mean temperature above median levels based on stratum-specific ORs" (5). The scholars were not able to tie increased asthma visits to specific pollution sources and calls for future research to determine whether increased pollutant concentrations or other inversion characteristics are responsible for the association and if inversion forecasts and air quality alert programs are valuable in mitigating these health concerns. Furthermore, the article describes the potential for misclassification of patients as a limitation. This is a good article to use for citing the association between inversions and negative health impacts.

Benney, Tabitha M, Devon Cantwell, Phillip Singer, Linda Derhak, Samuel Bey, and Zahra Saifee. "Understanding Perceptions of Health Risk and Behavioral Responses to Air Pollution in the State of Utah (USA)." *Atmosphere* 12, no. 11 (2021): 1373. DOI: 10.3390/atmos12111373

Most Utahns from both high- and low-income brackets are unaware of the long-term and short-term health impacts of air pollution. This is unfortunate considering Utah's current air quality issues and because Utah is becoming more susceptible to an increased number of unhealthy air days. More refined research is being published on air quality and the topic has also gained more attention in the media; yet people in Utah remain unaware of the long-term and short-term health impacts. Overall, this research suggests that most Utahns are uneducated about air quality, air pollutants, and the overall health impacts.

Broderick, Áine, Miriam Byrne, Sean Armstrong, Jerome Sheahan, and Ann Marie Coggins. "A Pre and Post Evaluation of Indoor Air Quality, Ventilation, and Thermal Comfort in Retrofitted Co-operative Social Housing." *Building and Environment* 122 (September 2017): 126-133. DOI: 10.1016/j.buildenv.2017.05.020

Energy upgrades on buildings (cavity and hollow walls, double-pane windows, roof isolation, and ventilation system) are a growing trend towards increasing efficiency, comfort, and household economic expenditure. However, little research focuses on measuring Indoor Air Pollutants before and after the upgrades. For this research, pollutants were measured by installing sensors inside and outside social housing, conducting building airtightness tests, measuring air exchange rates, and surveying occupants on comfort satisfaction. Results presented a greater satisfaction level on comfort by occupants, improvement of building airtightness, efficiency on energy consumption but with a significant increase in $PM_{2.5,}$ formaldehyde, Volatile Organic Compounds (VOC), and less ventilation. Although the increase in pollutants is related to installing new materials, it is also to human behaviors (smoking, fireplace use, vacuuming, and cleaning products). This research unveils the importance of long-term measures on buildings retrofitting to understand indoor air quality and the potential impacts of reducing ventilation by increasing efficiency.

Environmental Law Institute. “Indoor Air Quality Guide for Tenants.” Accessed April 15, 2022. https://www.eli.org/sites/default/files/docs/iaq_tenants_guide_10_17.pdf

This Environmental Law Institute guide serves as a resource for tenants to learn more about indoor air quality. The report outlines several common causes of poor IAQ in housing units (e.g., mold, secondhand smoke, poor ventilation, etc.), prevention and mitigation options, relevant policies throughout the United States, and resources for finding and interpreting state and local laws. Understanding relevant IAQ and housing policies is vital for tenants who need to address poor indoor air quality conditions in their rental units. Although policies targeting these specific issues are limited, they fall into three main categories. First, housing codes enforce general housing standards and require property owners to address code violations when they are made. Housing codes often do not explicitly mention indoor air quality and instead enforce standards that, by extension, maintain or improve adequate IAQ conditions (for example, regulations will usually require properties to be free of pests). Second, landlord-tenant laws outline the rights and responsibilities of both parties and, while more general than housing codes, establish basic requirements to maintain a safe, clean, and functioning property. Last, some laws directly target specific IAQ-related issues, although these are less commonplace than the previous two policy types.

Gonzalez, Andres, Adam Boies, Jacob Swanson, David Kittelson. “Measuring the Effect of Ventilation on Cooking in Indoor Air Quality by Low-Cost Air Sensors.” *International Journal of Environmental and Ecological Engineering* 13, no. 9 (2019): 568 - 576. DOI: 10.5281/zenodo.3455739

Fuel source, cooking appliance type, and method of cooking can negatively affect IAQ. Natural and mechanical ventilation systems can significantly reduce the longevity of pollutants indoors. Opening windows proved to be the most effective form of ventilation in this study. Low-cost, mobile air quality monitoring (LCMAQM) sensors, which are $150-200 per sensor, can be placed in homes and indoor facilities to measure gases (CO and CO_2) and particles ($PM_{2.5}$ and lung deposited surface area, below 100 nm). However, there are some limitations to LCMAQM sensors because they are not as accurate as an air monitoring station and require controlled humidity and temperature settings. Despite these limitations, local government and housing authorities could use these cost-effective sensors to monitor IAQ levels in residential homes, apartment complexes, and public facilities in Salt Lake City.

Hahnenberger, Maura, and Kevin D Perry. "Chemical Comparison of Dust and Soil from the Sevier Dry Lake, UT, USA." *Atmospheric Environment (1994)* 113 (2015): 90-97. DOI: 10.1016/j.atmosenv.2015.04.054

The Great Basin is a significant source of dust and particulate matter pollution (PM) for Utah’s metropolitan areas. PM pollution from the Great Basin is transported by air currents moving across Utah. The chemical composition of dust and soil emitted from the Great Basin has elevated levels of potentially hazardous elements including lead, arsenic, nickel, and chromium. Sevier Dry Lake is one of numerous defined dust sources downwind of Utah’s heavily populated areas. The atmospheric transport of dust and soil locally, regionally, and globally has detrimental effects on human health, ecosystem functions, and biochemical cycles.

Kwok Wai Tham. "Indoor air quality and its effects on humans—A review of challenges and developments in the last 30 years.” *Energy and Buildings* 130, no. 15 (2016): 637-650. DOI: 10.1016/j.enbuild.2016.08.071

A systematic literature review between 1986 and 2016 is analyzed in this document to comprehend indoor air quality (IAQ) as a multidisciplinary phenomenon from chemical, biological and physical

sources. The author starts by summarizing reviews from other publications and the impacts of indoor air pollution, including sources and health repercussions. Remarkably, there is a concern about adopting building efficiency regulations that do not comply with ventilation and prevention of airborne contaminants transmission. Some implications consider the lack of capacity to provide solutions to a myriad of factors on IAQ. In this view, a context with significant societal developments resonates with IAQ, such as climate change, building industry, urban form, childcare facilities as a spread of contaminants, deficient ventilation systems, long-term deposits of contaminants in surfaces that become a hazard when temperature increases, and intensive application of chemicals that disrupt endocrine functions and affect humans' genetics. The document concludes by providing emerging solutions such as prevention (informative programs on potential contaminants and identifying sources) and mitigation actions (air filtration, monitoring, and distribution technologies).

Lin, Beiyu, Yibo Huangfu, Nathan Lima, Bertram Jobson, Max Kirk, Patrick O'Keeffe, Shelley N Pressley, Von Walden, Brian Lamb, and Diane J Cook. "Analyzing the Relationship between Human Behavior and Indoor Air Quality." *Journal of Sensor and Actuator Networks* 6, no. 3 (2017). DOI: 10.3390/jsan6030013

Three major sources of indoor air pollution are outdoor pollutants, indoor combustion/cooking, and chemical products/indoor materials. The dynamic nature of human behavior requires a more technologically advanced method of frequent air quality monitoring in residential homes. Smart home technology with built-in chemical sensors and activity recognition software is a way to gather accurate, widely fluctuating IAQ data as behaviors change throughout the day. IAQ data from this study were collected during wildfire events, which resulted in more indoor activity and greater levels of outdoor particulate matter in highly frequented areas within the home (bathroom, kitchen, dining room). The relationship between temperature and indoor activities affects the length of exposure to indoor air pollution (temperature may prolong exposure even if the activity has ended). This data can be used to help researchers, local government officials, and housing authorities learn more about smart home technology and pinpoint specific human behaviors that have the greatest impact on IAQ.

Lin, John C, Logan Mitchell, Erik Crosman, Daniel L Mendoza, Martin Buchert, Ryan Bares, Ben Fasoli, David R Bowling, Diane Pataki, Douglas Catharine, Courtenay Strong, Kevin R Gurney, Risa Patarasuk, Munkhbayar Baasandorj, Alexander Jacques, Sebastian Hoch, John Horel, and Jim Ehleringer. "CO_2 and Carbon Emissions from Cities." *Bulletin of the American Meteorological Society* 99, no. 11 (2018): 2325-340. DOI: 10.1175/BAMS-D-17-0037.1

The Salt Lake Valley Greenhouse Gas Monitoring System gives geographic and spatial information about "where, how, and why" anthropogenic emissions vary in space and time across Salt Lake County. Anthropogenic greenhouse gas (GHG) emissions are mainly a result of the combustion of fossil fuels and come from a variety of sources including traffic. The combustion of fossil fuels are associated with several air pollutants including the main culprit of climate change—Carbon Dioxide (CO_2). There are some identified hotspots and peak periods for air pollutants across the Salt Lake Valley associated with the season, traffic, rush hour, and socioeconomic activities (e.g., 4^{th} of July Fireworks). This data can be used to inform stakeholders and help government agencies and policymakers make decisions to meet air pollution mitigation targets.

Malek, Esmaiel, Tess Davis, Randal S Martin, and Philip J Silva. "Meteorological and Environmental

Aspects of One of the Worst National Air Pollution Episodes (January, 2004) in Logan, Cache Valley, Utah, USA." *Atmospheric Research* 79, no. 2 (2006): 108-22. DOI: 10.1016/j.atmosres.2005.05.003

This article looks at the worst air quality reported nationally in Logan (Cache Valley) during January 2004. Malek, David, Martin, and Silva set out to explain this significant bad air quality day by

attending to meteorological and air pollution sources/formation factors. Meteorological factors examined were atmospheric pressure, wind, humidity, precipitation, solar radiation, and surface temperature and weather conditions. The scholars note that "The combination of temperature inversion, very cold temperatures, and lack of enough precipitation and/or strong winds, resulted in stagnant air in the valley with no tendency for vertical movement" (118). The primary pollutant sources include motor vehicles, wood stove combustion, and agricultural sources of ammonium which combines with nitric acid to form ammonium nitrate. The article ends with suggestions to reduce use of cars during inversions through increasing public transportation and carpooling, limiting drive throughs, and encouraging continual vehicle inspections and maintenance. Malek, David, Martin, and Silva also recommend future research on reducing ammonium from animal products. This article provides a good overview of varied factors that contribute to high air quality in the winter in our region and gestures towards some practices and policies that could limit these problems within Cache Valley.

Mendoza, Daniel L, Tabitha M Benney, and Sarah Boll. "Long-term analysis of the relationships between indoor and outdoor fine particulate pollution: A case study using research grade sensors." *Science of The Total Environment* 776 (2021). DOI: 10.1016/j.scitotenv.2021.145778

In this study, Mendoza et al. examine the relationship between outdoor and indoor air conditions by measuring $PM_{2.5}$ levels at a specific location for one year. Research-grade sensors were placed inside and outside the Unified State Laboratories building in Taylorsville, Utah to compare these conditions, particularly during three major elevated pollution event types: seasonal wildfire, winter inversion, and local fireworks. Several wildfires occurred throughout the study's year-long measurement period. During these wildfire events, sensor readings show that the differences between $PM_{2.5}$ concentrations indoors and outdoors were smaller than those measured on both baseline days and winter inversion events. While outdoor and indoor $PM_{2.5}$ concentrations did not exhibit the same drastic differences during winter inversion events, sensors show that, generally, as outside air conditions worsen during the valley's inversion, inside conditions worsen too. Notably, sensors reported extreme spikes in $PM_{2.5}$ concentrations during and directly after firework events. Throughout these periods, concentrations would increase sporadically both inside and outside for several hours at a time, causing red and sometimes even purple Air Quality Index (AQI) conditions. Based on these results, Mendoza et al. conclude that indoor air quality conditions during elevated pollution events should influence building infrastructure, reactive measures (e.g., use of air filters, enhanced filtration systems, etc.), and public health policymaking.

Peery, Lexi. "Utah Had the Worst Air in the World Today—Here's What You Need to Know to Be Safe." (August 6, 2021). https://www.kuer.org/health-science-environment/2021-08-06/utah-had-the-worst-air-in-the-world-today heres-what-you-need-to-know-to-be-safe

This short article provides a good example of community outreach during poor air quality days within the summer of 2021. The article starts by talking about details of where the fire is coming from and ends with a set of recommendations for mitigation. This could provide a good format for reaching out to the public during poor air quality events in the summer and some easy mitigation strategies that can

be recommended when wildfires are the main source and concern for indoor air quality.

Seguel, Joseph M, Richard Merrill, Dana Seguel, and Anthony C Campagna. “Indoor air quality.” *American Journal of Lifestyle Medicine* 11, no. 4 (2017): 284-295. DOI: 10.1177/1559827616653343

In this article, Seguel et al. comprehensively outline drivers of indoor air pollution, their impacts on human health, and potential solutions for better health outcomes. These causes include secondhand smoke, radon, carbon monoxide, nitrogen dioxide, formaldehyde, household cleaning and cooking
behaviors and products, mold, animal dander, dust mites, and household pests, all of which are common drivers of indoor air pollution in the United States. Impacts on human health vary widely depending on the driver, level of exposure, socioeconomic conditions, and preexisting health conditions (e.g., lung disease). Additionally, mitigation efforts to reduce health risks associated with indoor air pollutants can range from simple behavioral changes (e.g., swapping cleaning products) to more expensive, physical changes to one’s indoor environment (e.g., professionally installing a radon mitigation system). Seguel et al. conclude by emphasizing the connection between IAQ and human health. While mitigation can be challenging, many interventions can be pursued to improve indoor air quality and people’s health and quality of life.

Tran, Vinh Van, Duckshin Park, and Young-Chul Lee. "Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality." *International Journal of Environmental Research and Public Health* 17, no. 8 (2020): 2927. DOI: 10.3390/ijerph17082927

This article provides a comprehensive overview of what indoor air quality is, the various sources that can impact indoor air quality, how indoor air quality effects human health, strategies for monitoring indoor air quality, and smart home and air purification technologies that can mitigate the impacts of indoor air quality. One of the most beneficial parts of this article is that it breaks down the pollutants into a table, lists sources of those pollutants, and their health impacts. I also found the distinction of Sick Building Syndrome (SBS) from Building-Related Illness (BRI) to be helpful for understanding the more specific health impacts indoor air quality can have. This article manages to do a comprehensive overview while providing detail that can make approaching indoor air quality research more manageable.

Uhde, Erik, and Nicole Schulz. “Impact of room fragrance products on indoor air quality.” *Atmospheric Environment* 106 (2017): 492-502. DOI: 10.1016/j.atmosenv.2014.11.020

Consumer products, such as diffusers, cleaning supplies, and air fresheners, can unknowingly release countless chemicals into the air and create an unhealthy indoor environment. This study tested over one hundred chemicals commonly found in air fresheners, candles, and household fragrances to measure the evaporative concentrations of these chemicals (volatile organic compounds, nitrogen oxides, carbon monoxide) over time. In addition, odorless solvents and seemingly solvent-free products were tested and produced high concentrations of air pollutants. Accidental spillage of solvents can also expose users of these consumer products to high concentrations of chemicals for a prolonged period. This is a particularly useful resource for tenants/residents because it educates people about consumer products as a source of indoor air pollution.

Yu, B F, Z B Hu, M Hiu, H L Yang, Q X Kong, and Y H Liu. “Review of research on air-conditioning systems and indoor air quality control for human health.” *International Journal of Refrigeration* 32 no. 1 (2009): 3-20. DOI: 10.1016/j.ijrefrig.2008.05.004

Air-conditioning systems (ACS) have become a standard to provide comfort in built environments. With the intention to increase efficiency for controlling temperature, humidity, and air exchange rate, there is, however, less attention to the indoor air quality that ACS produces. In this document, the author comments on this gap by reviewing the literature on particle and gaseous pollutants and their interaction with diverse ACS. Three of them are analyzed in their efficiency on temperature comfort while maintaining good IAQ, including DOAS (Dedicated outdoor air system), ICTHS (Independent

control of temperature and humidity system), and CC/DV (Cooling ceiling and displacement ventilation), as well as air supply modes such as displacement ventilation, personalized ventilation, and under-floor air distribution. Control of IAQ pollutants is a concern that includes identification of pollutant sources (outdoor air, intercrossing infection, decorating and building materials) and air purification with filtration, adsorption, photocatalytic oxidation, negative air ions, and non-thermal plasma systems. With divergent efficiency levels, all of them face limitations due to the complexity of indoor pollutants, which leads to secondary pollutant types, complications in measuring impacts, and high energy consumption during operation. The author highlights the importance of combining technologies to increase system performance and IAQ.