The Indoor Housing Environment and Childhood Asthma –

A Limited Summary and Bibliography of the Research on Asthma Triggers

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The indoor environment contains potentially numerous exposures to conditions that are suspected to influence the development, prevalence, and incidence of asthma. Exposures include biologics (allergens, bacteria, or fungi), pollutant gases, and particulate matter from indoor (e.g., gas stoves and cigarette smoke) and outdoor sources. Known indoor allergens and irritants include the house dust mite, domestic pets, mold, cockroach, mouse, environmental tobacco smoke, endotoxin, and air pollution.

Minimizing exposure to allergens and remediating the environment play a critical role in the treatment of asthma and allergies. The most effective environmental control measures are tailored multifaceted interventions which include education, thorough cleaning, using high-efficiency particulate air (HEPA) filters, integrated pest management, and maintenance of these practices.

Gold, D. R., Adamkiewicz, G., Arshad, S. H., Celedón, J. C., Chapman, M. D., Chew, G. L., ... & Matsui, E. C. (2017). NIAID, NIEHS, NHLBI, and MCAN Workshop Report: the indoor environment and childhood asthma—implications for home environmental intervention in asthma prevention and management. *Journal of Allergy and Clinical Immunology*, *140*(4), 933-949.

Rosenfeld, L., Chew, G. L., Rudd, R., Emmons, K., Acosta, L., Perzanowski, M., & Acevedo-García, D. (2011). Are building-level characteristics associated with indoor allergens in the household?. *Journal of Urban Health*, *88*(1), 14-29.

Salo, P. M., Arbes Jr, S. J., Crockett, P. W., Thorne, P. S., Cohn, R. D., & Zeldin, D. C. (2008). Exposure to multiple indoor allergens in US homes and its relationship to asthma*. Journal of Allergy and Clinical Immunology*, *121*(3), 678-684.

**Response to allergens – the asthma response**

Allergy is classically manifested by an IgE antibody response to something that is normally considered harmless, typically a protein. When an allergen or microbial particle (e.g., found in house dust) is inhaled there are a variety of adverse and protective airway responses. What determines the response is affected by the type of allergen, the length of time of exposure and an individual susceptibility to have an airway response to the allergen molecules or particles.

When both are present, they may interact resulting in more severe responses. This may be particularly true in the presence of pollutants such as tobacco smoke.

**Possible Asthma Triggers**

**Dust Mites**

Dust mites are arachnids that infest bedding, carpet, upholstered furniture, and fabric. Their main food source is human skin scales, and they grow best in warm, humid environments. The most common species of the house dust mite (HDM) are *Dermatophagoides pteronyssinus* and *D. farinae*. Dust mite allergens are the only class of inhalant allergens for which the National Academy of Sciences for which a causal association between exposure and the development of asthma has been established. Exposure to dust mite allergen is also associated with asthma exacerbations. Dust mite exposure has been associated with dust mite sensitization.

Research suggests the most effective long-term strategy for HDM control is a *comprehensive plan* which includes cleaning regularly, washing and drying bedding weekly in high heat, using impermeable HDM covers (i.e., mattress covers), maintaining humidity indoors below 50%, and avoiding the use of carpet, upholstered furniture, and stuffed animals.

Conrad, L., & Perzanowski, M. S. (2019). The Role of Environmental Controls in Managing Asthma in Lower-Income Urban Communities. *Clinical Reviews in Allergy & Immunology*, *57*(3), 391-402.

Krieger, J., Jacobs, D. E., Ashley, P. J., Baeder, A., Chew, G. L., Dearborn, D., ... & Zeldin, D. C. (2010). Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence. *Journal of Public Health Management and Practice*, *16*(5 0), S11-S20.

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**Cockroaches**

The most common species of cockroach that cause sensitization are *Blattella germanica* (German cockroach) and *Periplaneta americana* (American cockroach). The major allergens are Bla g 1, Bla g 2, and Per a 1, which are found in saliva, secretions, debris, and fecal material.

Insect pests and pest allergens are difficult to eliminate. The goal is to reduce pest allergen by reducing the population of pests. Integrated Pest Management (IPM) which comprises an array of techniques including education, removing food sources, cleaning surfaces, using traps, and applying insecticides, repair structural defects including plugging holes, caulking, metal mesh, or expandable spray foams and gels and require long-term care to prevent re-infestation that focus on non-synthetic chemicals is the best approach.

Comparative studies of (IPM) and conventional chemical-based control methods have shown that IPM is the more effective approach to cockroach abatement. However, it can be costly and difficult to implement.

Conrad, L., & Perzanowski, M. S. (2019). The role of environmental controls in managing asthma in lower-income urban communities*. Clinical Reviews in Allergy & Immunology*, *57*(3), 391-402.

Rabito, F. A., Carlson, J. C., He, H., Werthmann, D., & Schal, C. (2017). A single intervention for cockroach control reduces cockroach exposure and asthma morbidity in children. *Journal of Allergy and Clinical Immunology*, *140*(2), 565-570.

Wright, L. S., & Phipatanakul, W. (2014). Environmental remediation in the treatment of allergy and asthma: latest updates. *Current Allergy and Asthma Reports*, *14*(3), 419-427.

**Mice & Rats**

The major mouse allergens include Mus m 1 and Mus m 2, which are found in mouse urine, dander, and hair follicles. Exposure to mouse allergen is associated with a high rate of allergen sensitization. High levels of mouse allergen have been associated with increased asthma morbidity. Rat allergens are found less frequently in about a third in dust samples in inner city homes. Their role in affecting asthma is less reported. Their allergenic risk may be less because they tend to dwell outdoors.

An IPM approach - The IPM intervention entailed vacuuming, using low toxicity pesticides, traps, and sealing holes can be effective. concluded the most effective strategies for abatement of rodents include preventing ingress, reducing clutter, and eliminating sources of food and shelter.

Grant, T., Aloe, C., Perzanowski, M., Phipatanakul, W., Bollinger, M. E., Miller, R., & Matsui, E. C. (2017). Mouse sensitization and exposure are associated with asthma severity in urban children. *The Journal of Allergy and Clinical Immunology: In Practice*, *5*(4), 1008-1014.

Matsui, E. C. (2013). Management of rodent exposure and allergy in the pediatric population. *Current Allergy and Asthma Reports*, *13*(6), 681-686.

Perry, T., Matsui, E., Merriman, B., Duong, T., & Eggleston, P. (2003). The prevalence of rat allergen in inner-city homes and its relationship to sensitization and asthma morbidity. *Journal of Allergy and Clinical Immunology*, *112*(2), 346-352.

**Environmental Tobacco Smoke**

Environmental tobacco smoke (ETS) is known to increase the prevalence of both upper and lower respiratory tract illnesses. Tobacco smoke exposure, even passive exposure leads to increased asthma symptoms and decreased response to inhaled corticosteroids. A systematic review and meta-analysis showed that exposure to passive smoking, especially pre- or postnatal maternal smoking, increases the risk of wheeze and the incidence of asthma at age 5 to 18 years. Although it is clearly evident that ETS is a major risk factor for asthma, studies have shown that it is difficult to effectively reduce ETS.

The efficacy in reducing indoor pollutants is dependent on room dimensions and building structure and conditions. Although air cleaners have been used as effective adjunct interventions in multipronged environmental intervention in reducing asthma symptoms, their independent contributions to health are uncertain, and the physical settings in which they might reduce exposure sufficiently to contribute to asthma control are not well defined.

One randomized control trial looked at use of air cleaners and a health coach to reduce particulate matter (from second-hand smoke) and found that air cleaners in homes of children with asthma lead to a significant reduction in indoor fine particulate matter (PM 2.5) concentrations and increased symptom free days; however, there was not a decrease in air nicotine or urinary cotinine. Another study showed that HEPA air cleaners led to significant reductions in unscheduled asthma visits and levels of fine airborne pollutants, but did not decrease asthma symptoms, cotinine levels, or exhaled nitric-oxide levels.

Burke, H., Leonardi-Bee, J., Hashim, A., Pine-Abata, H., Chen, Y., Cook, D. G., ... & McKeever, T. M. (2012). Prenatal and passive smoke exposure and incidence of asthma and wheeze: systematic review and meta-analysis. *Pediatrics*, *129*(4), 735-744.

Butz, A. M., Matsui, E. C., Breysse, P., Curtin-Brosnan, J., Eggleston, P., Diette, G., ... & Rand, C. (2011). A randomized trial of air cleaners and a health coach to improve indoor air quality for inner-city children with asthma and secondhand smoke exposure. *Archives of Pediatrics & Adolescent Medicine*, *165*(8), 741-748.

Jing, W., Wang, W., & Liu, Q. (2019). Passive smoking induces pediatric asthma by affecting the balance of Treg/Th17 cells. *Pediatric Research*, *85*(4), 469-476.

Lanphear, B. P., Hornung, R. W., Khoury, J., Yolton, K., Lierl, M., & Kalkbrenner, A. (2011). Effects of HEPA air cleaners on unscheduled asthma visits and asthma symptoms for children exposed to secondhand tobacco smoke. *Pediatrics*, *127*(1), 93-101.

McCarville, M., Sohn, M. W., Oh, E., Weiss, K., & Gupta, R. (2013). Environmental tobacco smoke and asthma exacerbations and severity: the difference between measured and reported exposure. *Archives of Disease in Childhood*, *98*(7), 510-514.

**Combustion by-products from Fossil Fuel**

Nitrogen dioxide (NO2) and other volatile gases are known respiratory irritants. The levels of exposure indoors to these gases are of concern because children spend considerable amount of their time indoors at home. Nitrogen dioxide (NO2) is a pollutant gas by-product of combustion from indoor sources such as gas stoves, heaters, and poorly ventilated furnaces and fireplaces. It has been shown to affect both allergic and non-allergic children with asthma. To the extent that gas appliances may confer a risk of respiratory symptoms, the exposure may be more complex than simply NO2. For example, gas stoves may also increase other indoor air pollutants, such as nitrous acid, hat may also adversely affect respiratory health

Increased ventilation with more open windows led to lower in-home particulate-matter concentration. Intervention studies have shown that high-efficiency particulate arrestor (HEPA) air filters are effective in lowering indoor particulate matter.

Other major gaseous pollutants include ozone and sulfur dioxide. Sulfur dioxide (SO2) is emitted from burning of sulfur-containing fossil fuels. Exposure to SO2 has been shown to cause bronchoconstriction and associated with increases in respiratory morbidity. Ozone is a potent oxidizing agent that is formed by a photochemical reaction between sunlight and pollutant precursors, particularly in warmer temperatures. Ozone exposure has long been shown to result in airway inflammation and hyper-responsiveness.

Instructing families to operate vents when using gas appliances as part of asthma education programs would be a simple and immediate intervention. Long-term efforts should be aimed at advocating for installing vents with gas appliances and the manufacture of pilotless stoves, which are associated with lower NO2 levels.

Belanger, K., Holford, T. R., Gent, J. F., Hill, M. E., Kezik, J. M., & Leaderer, B. P. (2013). Household levels of nitrogen dioxide and pediatric asthma severity. *Epidemiolog*y (Cambridge, Mass.), *24*(2), 320-330.

Diette, G. B., McCormack, M. C., Hansel, N. N., Breysse, P. N., & Matsui, E. C. (2008). Environmental issues in managing asthma. *Respiratory Care*, *53*(5), 602-617.

Kattan, M., Gergen, P. J., Eggleston, P., Visness, C. M., & Mitchell, H. E. (2007). Health effects of indoor nitrogen dioxide and passive smoking on urban asthmatic children. *Journal of Allergy and Clinical Immunology*, *120*(3), 618-624.

Matsui, E. C., Abramson, S. L., & Sandel, M. T. (2016). Indoor environmental control practices and asthma management. *Pediatrics*, *138*(5):e20162589.

**Mold**

Mold and moisture have been associated with poor health outcomes, such as upper respiratory tract symptoms, cough, wheeze, and other asthma symptoms. Mold is associated with exacerbation of allergic rhinitis and allergic asthma in people who are sensitized to mold. Some components of mold also may elicit inflammation via non-allergic mechanisms.

There are many species of mold, but common molds include *Alternaria, Cladosporium, Aspergillus,* and *Penicillium*. Of all the molds, the most thoroughly investigated is *Alternaria*. In inner-city children with asthma, *Alternaria* sensitization has been associated with an increased risk of asthma-related hospitalization.

Indoor fungi originate through penetration from both outdoor and indoor sources, especially in damp and water-damaged buildings. Fungi and their irritant or toxicant components can have adverse airway irritant and allergenic properties, and asthma symptoms can occur in both subjects who are not sensitized and those who are sensitized to fungi. Mechanisms for the effects of individual fungal components and interactive effects with other indoor exposures on airway and immune responses are not well understood.

Indoor environmental factors that influence the presence of dampness and the concentration of molds within homes include modifiable risk factors such as residential characteristics, the built environment, and behavior, which, when altered, can in turn lower allergy burden.

One study examined mold remediation in the homes of 62 inner-city asthmatics randomly assigned to intervention and control and found that an intervention which included repair of leaks, removal of water-damaged materials, ventilation alteration, and decreasing the humidity in damp basements resulted in children having fewer emergency rooms and hospitalizations and reduction in asthma symptom days after mold remediation compared to children in the control group.

Another study showed that a comprehensive program including community health care worker in home education in combination with weatherization (defined as home air tightness measurements, combustion safety testing, heating system assessment, and assessment of moisture related problems) and healthy home interventions to reduce asthma triggers lead to a statistically significant reduction in visible mold and improved asthma control and caregiver quality of life.

Breysse, P. N., Diette, G. B., Matsui, E. C., Butz, A. M., Hansel, N. N., & McCormack, M. C. (2010). Indoor air pollution and asthma in children. *Proceedings of the American Thoracic Society*, *7*(2), 102-106.

Kercsmar, C. M., Dearborn, D. G., Schluchter, M., Xue, L., Kirchner, H. L., Sobolewski, J., ... & Allan, T. (2006). Reduction in asthma morbidity in children as a result of home remediation aimed at moisture sources. *Environmental Health Perspectives*, *114*(10), 1574-1580.

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Sharpe, R., Thornton, C. R., & Osborne, N. J. (2014). Modifiable factors governing indoor fungal diversity and risk of asthma. *Clinical & Experimental Allergy*, *44*(5), 631-641.

**Pets**

Allergic sensitization to furred pet allergens is quite common, and in some populations more than 60% of children with asthma are sensitized to cat or dog allergens. The primary cat allergen is Fel d 1, which is found in saliva, skin, and hair follicles. Cat allergen is carried on small particles, ranging from 2 to 10 microns, which allows it to remain airborne and become adherent to surfaces and clothing. The major dog allergen is Can f 1, which is also found in saliva, skin, and hair follicles.

One investigation found that after cat removal, it takes 20–24 weeks to reduce cat allergen levels in the indoor environment. After aggressive cleaning of the upholstered furniture, cat allergen decreases more rapidly. Another potential collection place of pet allergen is the mattress; thus, encasings are recommended as part of a comprehensive approach to reduce allergen levels. Regular washing of pets reduces allergen levels; however, the effects are not sustained. Washing cats demonstrated no benefit or transient benefit (not sustained beyond 1 week). Similarly, that dog washing has been found to reduce dog allergen levels the results are temporary unless a dog is washed twice a week.

The American Academy of Allergy and Immunology (AAAAI) practice recommendation is for furry animals that hypoallergenic cats and dogs should not be recommended for sensitized individuals. In part this recommendation is made based on the debate that there are “hypoallergenic” pets. One study while higher Can f1 levels were found in hair and coat samples of hypoallergenic dog breeds compared to non-hypoallergenic dog breeds there was no difference in dog allergen levels in settled dust and airborne samples between the two breeds however, there was no difference in dog allergen levels in settled dust and airborne samples between the two breeds.

HEPA filters may help in reducing cat allergen levels and may increase some allergic reaction responsivity. But HEPA filter use is unlikely to improve symptoms and medication use for a sustained period of time.

Ahluwalia, S. K., & Matsui, E. C. (2018). Indoor environmental interventions for furry pet allergens, pest allergens, and mold: looking to the future. *The Journal of Allergy and Clinical Immunology: In Practice*, *6*(1), 9-19.

Vredegoor, D. W., Willemse, T., Chapman, M. D., Heederik, D. J., & Krop, E. J. (2012). Can f 1 levels in hair and homes of different dog breeds: lack of evidence to describe any dog breed as hypoallergenic. *Journal of Allergy and Clinical Immunology*, *130*(4), 904-909.

Sampling of Other Work

**Intervention/Remediation Programs**

Crocker, D. D., Kinyota, S., Dumitru, G. G., Ligon, C. B., Herman, E. J., Ferdinands, J. M., ... & Task Force on Community Preventive Services. (2011). Effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity: a community guide systematic review.*American Journal of Preventive Medicine, 41*(2), S5-S32*.*

[Gruber, K. J., McKee-Huger, B., Richard, A., Byerly, B., Raczkowski, J. L., & Wall, T. C. (2016). Removing asthma triggers and improving children's health: The Asthma Partnership Demonstration project. *Annals of Allergy, Asthma & Immunology*, *116*(5), 408-414.](http://betterhealthpartnership.org/pdfs/lc_presentations/2018_04/lc_22_lead_and_asthma_related_link_03.pdf)

Krieger, J. W., Takaro, T. K., & Rabkin, J. C. (2011). Breathing easier in Seattle: addressing asthma disparities through healthier housing. In *Healthcare Disparities at the Crossroads with Healthcare Reform*(pp. 359-383). Springer, Boston, MA.

Largo, T. W., Borgialli, M., Wisinski, C. L., Wahl, R. L., & Priem, W. F. (2011). Healthy Homes University: a home-based environmental intervention and education program for families with pediatric asthma in Michigan. *Public Health Reports, 126*(1\_suppl), 14-26.

Morgan, W. J., Crain, E. F., Gruchalla, R. S., O'Connor, G. T., Kattan, M., Evans III, R., ... & Mitchell, H. (2004). Results of a home-based environmental intervention among urban children with asthma. *New England Journal of Medicine*, *351*(11), 1068-1080.

Takaro, T. K., Krieger, J., Song, L., Sharify, D., & Beaudet, N. (2011). The Breathe-Easy Home: the impact of asthma-friendly home construction on clinical outcomes and trigger exposure. *American Journal of Public Health*, *101*(1), 55-62.

Townsend, K. J., & George, M. (2011). What is the evidence that environmental remediation programs are effective in urban children with allergic asthma? An integrated review*. Journal of Asthma & Allergy Educators*, *2*(6), 295-305.

Turcotte, D. A., Alker, H., Chaves, E., Gore, R., & Woskie, S. (2014). Healthy homes: in-home environmental asthma intervention in a diverse urban community*. American Journal of Public Health*, *104*(4), 665-671.

Wright, L. S., & Phipatanakul, W. (2014). Environmental remediation in the treatment of allergy and asthma: latest updates. *Current Allergy and Asthma Reports*, *14*(3), 419-427.

**Housing Code Violations**

Beck, A. F., Huang, B., Chundur, R., & Kahn, R. S. (2014). Housing code violation density associated with emergency department and hospital use by children with asthma. *Health Affairs*, *33*(11), 1993-2002.

**Association of Childhood Asthma with Federal Rental Assistance**

Boudreaux, M., Fenelon, A., Slopen, N., & Newman, S. J. (2020). Association of childhood asthma with federal rental assistance. *JAMA Pediatrics*, *174*(6), 592-598.

**Home Visits for Pediatric Asthma**

Anderson, M. E., Zajac, L., Thanik, E., & Galvez, M. (2020). Home visits for pediatric asthma-A strategy for comprehensive asthma management through prevention and reduction of environmental asthma triggers in the home. *Current Problems in Pediatric and Adolescent Health Care*, *50*(2), 100753.

Breysse, J., Dixon, S., Gregory, J., Philby, M., Jacobs, D. E., & Krieger, J. (2014). Effect of weatherization combined with community health worker in-home education on asthma control. *American Journal of Public Health*, *104*(1), e57-e64.

**Social Determinants of Health**

Federico, M. J., McFarlane II, A. E., Szefler, S. J., & Abrams, E. M. (2020). The impact of social determinants of health on children with asthma. *The Journal of Allergy and Clinical Immunology: In Practice*, *8*(6), 1808-1814.

**Why Interventions May Not (Appear) to Work**

1. The volume or intensity of the intervention may fail to sufficiently reduce an exposure.

2. If the individual is not sensitized or exposed to the targeted allergen of the intervention, there will not be a significant improvement.

3. Reducing exposure in one location, but not all, will likely be ineffective

4. The intervention may be inadequate to reduce the level of allergen or airway irritant

5. All sources of irritants may not be addressed with one intervention approach

O'Connor, G. T. (2005). Allergen avoidance in asthma: what do we do now?. *Journal of Allergy and Clinical Immunology*, *116*(1), 26-30.

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