Indoor Air Quality, Allergic Airway Diseases

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Medical Director, Center for Environmental Medicine, Asthma and Lung Biology
UNC School of Medicine

Indoor Air Pollution

Types of indoor pollutants:
- Particulate Matter
  - PM$_{2.5}$
- NO$_2$
- Endotoxins

Sources of Air Pollution:
- PM generated with cooking, especially use of indoor biomass as fuel
- Indoor fireplaces
- Smoking
- Biologicals (bacteria, fungi, allergens)
Indoor air pollutants
Impact on asthma

Patrick N. Breysse; Gregory B. Diette; Elizabeth C. Matsui; Arlene M. Butz; Nadia N. Hansel; Meredith C. McCormack; *Proc Am Thorac Soc* 2010 7102-106. © 2010 The American Thoracic Society

Figure 1. Comparison of particulate matter (PM) concentrations simultaneously measured indoors, immediately outdoors, and at a central monitoring site.
Figure 2. Distributions of indoor PM in the child's bedroom.

Figure 3. Indoor PM concentrations, asthma symptoms, and rescue medication use: multivariate models (coarse module adjusted for age, sex, race, parent education level, season, indoor fine PM, ambient fine PM, ambient coarse PM; fine module adjusted for age, sex, race, parent education level, season, indoor coarse PM, ambient coarse PM, ambient fine PM).
Figure 4. Risk of asthma symptoms per 20 ppb increase in NO2 exposure, adjusted for PM2.5; second hand smoke; distance from the curb; type of street in front of house; season of sampling; age, sex, and race of child; and mother's education level.

Adverse health effects associated with household air pollution: a systematic review, meta-analysis, and burden estimation study
Lee KK, et al. The Lancet Global Health
Volume 8 Issue 11 Pages e1427-e1434 (November 2020)
DOI: 10.1016/S2214-109X(20)30343-0

<table>
<thead>
<tr>
<th>Health Effect</th>
<th>Number of estimates</th>
<th>Pooled relative risk (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiratory diseases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td>119</td>
<td>1.23 (1.11-1.36)</td>
</tr>
<tr>
<td>COPD</td>
<td>108</td>
<td>1.70 (1.47-1.97)</td>
</tr>
<tr>
<td>ARI (adults)</td>
<td>23</td>
<td>1.53 (1.22-1.93)</td>
</tr>
<tr>
<td>ARI (paediatric)</td>
<td>123</td>
<td>1.39 (1.29-1.49)</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>82</td>
<td>1.69 (1.44-1.98)</td>
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<tr>
<td>Tuberculosis</td>
<td>53</td>
<td>1.26 (1.08-1.48)</td>
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<tr>
<td>Respiratory disease*</td>
<td>33</td>
<td>1.31 (1.25-1.37)</td>
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<tr>
<td><strong>Cardiovascular diseases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>13</td>
<td>1.09 (1.04-1.14)</td>
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<tr>
<td>Ischaemic heart disease</td>
<td>13</td>
<td>1.10 (1.05-1.15)</td>
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<tr>
<td>Cardiovascular events</td>
<td>11</td>
<td>1.13 (1.05-1.22)</td>
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<tr>
<td><strong>Adverse pregnancy outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low birthweight</td>
<td>29</td>
<td>1.36 (1.19-1.55)</td>
</tr>
<tr>
<td>Stillbirth</td>
<td>37</td>
<td>1.22 (1.06-1.41)</td>
</tr>
</tbody>
</table>
Environmental Endotoxin

Impact on asthma

Environmental endotoxin exposure and asthma
Peter S. Thorne, MS, PhD
Journal of Allergy and Clinical Immunology
Volume 148 Issue 1 Pages 61-63 (July 2021)
DOI: 10.1016/j.jaci.2021.05.004

A
Mean Airborne Endotoxin Concentration

B
Mean Reservoir Dust Endotoxin Concentration

Endotoxin Concentration, EU/m³
Figure 1. Smoothed plots of prevalence of disease outcomes versus the unweighted, combined bed and bedroom floor dust endotoxin concentration (expressed as endotoxin units per milligram of dust [EU/mg]). (A) The prevalence of wheeze in the past 12 months. (B) The prevalence of doctor-diagnosed asthma. (C) The prevalence of current asthma. (D) The prevalence of the combined outcomes of current asthma and wheeze in the past 12 months. All four plots show a nearly linear increase of the respiratory health outcomes with the endotoxin concentration log values. Solid lines show the smoothed mean prevalence, and dashed lines indicate upper and lower 95% confidence intervals.

Figure 2. Forest plots for coexposures to endotoxin and air pollutants synergistically associated with emergency room visits for asthma in the past 12 months. Air pollutant data were obtained using the Community Multiscale Air Quality Modeling System. The models were adjusted for age, sex, race/ethnicity, smoker in household, poverty/income ratio, body mass index, census region, and level of urbanization. The squares indicate the odds ratios, and the lines indicate the 95% confidence intervals (CIs) for the odds ratios (ORs). *P < 0.05, **P < 0.01, ***P < 0.001, and ****P < 0.0001. NO2 = nitrogen dioxide, PM2.5 = particulate matter ≤2.5 μm in aerodynamic diameter.
Endotoxin enhances response to allergen

Interventions
HEPA Filters

Fig. 1. Flow chart including the study population in the different steps of the methodology. Grey boxes represent the health outcomes considered. PFT – Pulmonary Function Test; SPT – Skin Prick Test.
Study Highlights

- Asthma was not associated with IAP inhaled dose in Portuguese pre/primary schools.
- Multipollutant dose models showed associations with respiratory health outcomes.
- Reported active wheezing was associated with high NO₂ exposure in schools.
- Reduced lung function was associated with high PM₂.₅ and O₃ exposure in schools.
- PM dose had distinct effects on allergen sensitised children.
<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Population</th>
<th>Intervention</th>
<th>Effectiveness of Intervention</th>
</tr>
</thead>
</table>
| Piotto et al. [88] (2004) | Randomized control trial | Children (aged 8-9 y; Australia) | Replacement fluid gas or electric heaters in schools | • Reduction in NO<sub>2</sub> exposure  
• Reduction in asthma symptoms |
| Jhun et al. [89] (2017) | Randomized control trial (Pilot Study) | Children (aged 6-10 y; USA) | Classroom based HEPA air cleaner intervention | • Reductions in PM<sub>2.5</sub> and BC  
• No significant changes in FEV<sub>1</sub> and asthma symptoms  
• Modest improvement in peak flow |
| Bernstein et al. [90] (2005) | Randomized control trial (Pilot Study) | Children (aged newborn-5 y; USA) | Dehumidification plus day care room based HEPA air cleaner | • Lower average dew point from baseline for both day care A and B  
• Reduction in fungal spore counts for day care A only  
• No health outcomes assessed |
| Lignell et al. [91] (2007) | Longitudinal intervention study | Children (aged 7-12 y; Finland) | Damaged school renovated for all identified problems, mechanical exhaust and supply air ventilation system installed | • 50% reduction in fungal concentrations  
• Modest reduction in respiratory symptoms |
| Meklin et al. [92] (2005) | Longitudinal intervention study | Children (aged 6-17 y; Finland) | Damaged schools thoroughly cleaned, repaired, renovated, and mechanical exhaust and supply ventilation system installed | • Normalization of indoor air fungal concentrations  
• Reduction in respiratory and other symptoms |
| Karlsson et al. [93] (2004) | Intervention study | Children (aged 6-12 y; Sweden) | School clothing or pet-free classes. Two classes of children with special school clothing, one class of children with no pets, and three control classes. | • 4-6 fold lower airborne cat allergen levels in intervention classes compared with controls.  
• No health outcomes assessed |
| Nalyanya et al. [94] (2009) | Longitudinal intervention study | Children (USA) | Integrated pest management (IPM) or conventional pest control | • Reduction in IgE g 1 concentrations in IPM-treated schools than in schools treated with conventional approaches.  
• No health outcomes assessed |

**Summary**

**Indoor air and allergic disease**
Summary

- Biomass burning, smoking, natural gas burning and humidity are important determinants of indoor air pollution and air quality
- HEPA filters provide a potential benefit with some studies showing clinical benefit
- Humidity control can be useful in reducing bioaerosols and allergens, including endotoxin
- Reducing or elimination smoking and biomass burning useful, though interventions studies are mixed-most show pollutant reduction, but borderline clinical benefit
- Indoor interventions should be multifactorial-usually one intervention is not sufficient
What every allergist needs to know about climate change

Aaron Bernstein, MD MPH
Hospitalist, Boston Children’s Hospital
Interim Director, Center for Climate Health & the Global Environment
Harvard TH Chan School of Public Health
Faculty Disclosure Information

I have had no relevant financial relationships with the manufacturer(s) of any commercial product(s) and/or provider(s) of commercial service(s) discussed in this lecture.

I do not intend to discuss an unapproved/investigative use of a commercial product/device in my presentation.
Pathways from greenhouse gas emissions to health outcomes

<table>
<thead>
<tr>
<th>Greenhouse Gases</th>
<th>Earth Systems</th>
<th>Mechanisms</th>
<th>Conditions/Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂, N₂O, CH₄</td>
<td>Sea Level Rise</td>
<td>Ozone</td>
<td>Heat-related Diseases</td>
</tr>
<tr>
<td></td>
<td>Higher Atmospheric CO₂</td>
<td>Water Shortages</td>
<td>Environmental Allergies</td>
</tr>
<tr>
<td></td>
<td>Floods &amp; Droughts</td>
<td>Lower Crop Yields</td>
<td>Maternal &amp; Newborn Outcomes</td>
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<tr>
<td></td>
<td>Higher Temperature</td>
<td>Wildfires</td>
<td>Respiratory Diseases</td>
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<tr>
<td></td>
<td></td>
<td>Corona virus.</td>
<td>Cardiovascular Disease</td>
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<td></td>
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<td>Population Migration</td>
<td>Vectorborne Diseases</td>
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<tr>
<td></td>
<td></td>
<td>Particulate Matter Air Pollution</td>
<td>Nutritional Diseases</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mental Health Disorders</td>
</tr>
</tbody>
</table>
Wildfires
The Camp Fire
November 8 - 25, 2018
~14,000 homes destroyed
86 deaths

Homes leveled by the Camp Fire line a development Paradise, Calif., Nov. 17, 2018.

Credit: California National Guard/Creative Commons License
In the West, forest fires burn more acres in a world warmed by climate change.

Source: Proceedings of the National Academy of Sciences; data updated through 2017 by A. Park Williams.
CAN WILDFIRE SMOKE MAKE YOU SICK?
PLUMES FROM WORST WILDFIRE IN CALIFORNIA HISTORY
REACH MASSACHUSETTS

BY ARISTOS GEORGIU ON 11/12/18 AT 12:49 PM
Smoke is bad for your health

Wildfire source PM may be more toxic than PM in general

- Acrolein
- Formaldehyde
- Benzene/PAHs
- PM$_{2.5}$
- NOx

Leukemia/lymphoma
Anxiety/depression
ADHD

Asthma (causal)
Respiratory infections
Early Life Wildfire Smoke Exposure Is Associated with Immune Dysregulation and Lung Function Decrement in Adolescence

Decreased lung function

DOI: 10.1165/rcmb.2016-0380OC on February 16, 2017

Altered immune responses
Effect of catastrophic wildfires on asthmatic outcomes in obese children: breathing fire

Prevalence of SABA Use Before vs. After 2003 Wildfires

Prevalence of SABA Use Before vs. After 2007 Wildfires

Pollen & Allergies
Shifting summer temperatures across the northern hemisphere 1951-2015

Source: Columbia University Earth Institute. Data via Makiko Sato and James Hansen. Based on: Hansen et al., 2012 (and discussion); 2016 update.
Anthropogenic climate change is worsening North American pollen seasons


Data from 60 pollen stations in North America.
Anthropogenic climate change is worsening North American pollen seasons

B pollen season start date and season length

Data from 60 pollen stations in North America.
Increased duration of pollen and mold exposure are linked to climate change.
Higher CO$_2$ Concentrations Promotes Pollen Production

Ragweed pollen production (g/plant)

1900 280ppm
2000 370ppm
2060 600ppm

Urban CO$_2$ Domes

Long-term urban carbon dioxide observations reveal spatial and temporal dynamics related to urban characteristics and growth.

PNAS March 20, 2018 115 (12) 2912-2917
The urban heat island effect
TOP 10 cities with fastest growing urban heat island

- Columbus (0.84°F per decade)
- Minneapolis (0.77°F per decade)
- Baltimore (0.66°F per decade)
- Louisville (0.65°F per decade)
- St. Louis (0.64°F per decade)
- Wichita (0.60°F per decade)
- Birmingham (0.58°F per decade)
- New Orleans (0.56°F per decade)
- Des Moines (0.56°F per decade)
- Oklahoma (0.55°F per decade)
Higher temperatures drive more ozone formation

Data for Washington DC
Meds
You are seeing an 8 year old boy with autism and seasonal allergies. He takes quetiapine and cogentin for behavioral regulation and desloratidine for allergies. Last week, his psychiatrist increased his quetiapine dose as his behaviors escalated.

His mother has brought him to see you for an urgent care visit because he’s been acting confused after he came home from playing outside for a few hours. He has complained of headache and nausea.

T 40.1 HR 130 BP 102/60 RR 22. He appears flush. His skin is diffusely red and dry. When asked what he was doing outside he said he had a great time dancing with wildcats.

What is your diagnosis?
Many antihistamines have anticholinergic effects

<table>
<thead>
<tr>
<th>Antagonist</th>
<th>Anticholinergic pA₂ (g pig trachea)</th>
<th>Antihistaminic pA₂ (g pig ileum published data)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyproheptadine</td>
<td>8.2±0.4</td>
<td>Not found</td>
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<tr>
<td>Promethazine</td>
<td>7.8±0.3</td>
<td>8.9</td>
</tr>
<tr>
<td>Desloratadine</td>
<td>6.9±0.4</td>
<td>8.2</td>
</tr>
<tr>
<td>Diphenhydramine</td>
<td>6.3±0.3</td>
<td>7.80</td>
</tr>
<tr>
<td>Loratadine</td>
<td>5.6±0.3</td>
<td>7.3</td>
</tr>
<tr>
<td>Chlorpheniramine</td>
<td>5.4±0.4</td>
<td>9.1, 9.6</td>
</tr>
<tr>
<td>Hydroxyzine</td>
<td>5.2±0.2</td>
<td>Not found</td>
</tr>
<tr>
<td>Pyrilamine</td>
<td>4.8±0.4</td>
<td>9.2</td>
</tr>
<tr>
<td>Cetirizine</td>
<td>Indeterminable</td>
<td>6.3 (g pig trachea)</td>
</tr>
<tr>
<td>Fexofenadine</td>
<td>Indeterminable</td>
<td>Not found</td>
</tr>
</tbody>
</table>

a Antilog[pA₂(histamine)−pA₂(carbachol)].

b Denotes ratio derived using the average of two pA₂ values.
At least in some populations, use of antihistamines may be increasing.
Heat may affect medication delivery devices

Single, short-time exposure to heat in a car during sunny day can decrease epinephrine concentration in autoinjectors.
Climate MD

Bringing climate impacts and solutions to the bedside.

The Climate Optimist

It's real. It's now. We have solutions.

Your monthly dose of good news about climate change.

Climate heroes are not only designing and building the healthier future we need; they are also defending against actions that threaten science and our health. This issue highlights key stories from this month.
Disparities in the Air We Breathe

Bridgette L. Jones, MD MS
Associate Professor of Pediatrics
University of Missouri Kansas City School of Medicine
Children’s’ Mercy

“New Orleans’ was already a place, a place with a name, before the first Europeans set sail for the area.” Known as “Bulbancha,” a Choctaw term meaning “place of many tongues” -Dr. Jeffery U. Darrensbourg, Tribal Councilperson and enrolled member of the Atakapa-Ishak Nation of Southwest Louisiana and Southeast Texas,

This place was originally inhabited by the Chitimacha nation and, prior to 1718, served as an important port and trading hub for more than 40 diverse peoples, including Atakapa, Caddo, Choctaw, Houma, Natchez, and Tunica nations. We pay respect to these communities
Disclosures

• Paid contributor to Merck manuals
• Paid contributor to Med Learning Group

Objectives

• Describe contributions to observed asthma/allergy related disparities
• Describe the impact of intuitional racism on environmental inequity
• Describe projections for future impacts of climate change on health disparities in the United States
• Describe additional “environmental factors” impacting allergy/asthma disparities
• Describe action steps towards environmental justice
Disparities in Asthma


Figure 5: Asthma healthcare utilization among children and adults with current asthma by race and ethnicity*: National Asthma Control Program Grantees,** 2010

Asthma death rates by age, sex, and race/ethnicity: National Asthma Control Program Grantees,* 2010

Source: National Vital Statistics System, National Center for Health Statistics, Centers of Disease Control and Prevention

*35 National Asthma Control Program Grantees (Puerto Rico is excluded)

1. Crude rate per million population
2. Age-adjusted rate per million population
3. Race categories are non-Hispanic
Social Determinants of Health

• The World Health Organization defines social determinants of health as “the conditions in which people are born, grow, live, work, and age.”
  • influenced by economic, political, and social factors linked to health inequities
    • avoidable inequalities in health between groups of people within populations and between countries
  • poverty, housing insecurity, child health equity, immigration status, and early childhood adversity
  • “Health equity means that everyone has a fair and just opportunity to be as healthy as possible” -Robert Wood Johnson Foundation
“Racism is a serious public health threat that directly affects the well-being of millions of Americans. As a result, it affects the health of our entire nation. Racism is not just the discrimination against one group based on the color of their skin or their race or ethnicity, but the structural barriers that impact racial and ethnic groups differently to influence where a person lives, where they work, where their children play, and where they gather in community.” - Rochelle P. Walensky, MD, MPH Director, CDC

“Racism is a core social determinant of health that is a driver of health inequities”

During the Great Depression, the federal government passed the Home Owners’ Loan Corporation Act. The Act created standardized criteria for determining credit-worthiness for neighborhoods in American urban centers. Credit-worthiness was highly dependent on the racial makeup of a particular neighborhood. White neighborhoods were designated as the “Best” areas for investment, while non-white areas were disproportionately designated as “Hazardous” or risky areas for investment. Cities developed Residential Security Maps that graded neighborhoods. Black neighborhoods often received the lowest grade and were shaded red on the map, hence the term “redlining.

INSTITUTIONAL RACISM. Occurs within and between institutions. Often manifests as discriminatory treatment, practices, and policies that result in inequitable opportunities and impacts for marginalized racialized groups and create and sustain racialized outcomes.
Asthma UC/ED/Hospitalization at Children’s Mercy >4 times Annual Visits, 2016-2018

Associations between historical residential redlining and current age-adjusted rates of emergency department visits due to asthma across eight cities in California: an ecological study

Nardone et al. The Lancet Planetary Health, 2020
• historically redlined districts are on average 5 degrees Fahrenheit warmer than non-redlined districts- in several instances, the difference in summer surface temperatures between redlined and non-redlined neighborhoods was as much as 20 F.

• “air pollution is “an epidemic” in minority communities where residents are “literally dying for a breath of fresh air.”” -Mustafa Santiago Ali, vice president for environmental justice, climate and community revitalization at the National Wildlife Federation


• Black and African American individuals are 40% more likely than non-Black and non-African American individuals to currently live in areas with the highest projected increases in mortality rates due to climate-driven changes in extreme temperatures.

EPA just detailed all the ways climate change will hit U.S. racial minorities the hardest. It’s a long list.

• Increased temperature
• Increased particulate matter/ozone/poor air quality
• Increased flooding/extreme weather- mold and other exposures
• Increased Wildfires
• Drought
Chronic stress exposure among young African American children with asthma

Racism is a factor

African American and Hispanic children are more likely to have a diagnosis of asthma and significantly higher disease-related morbidity in comparison with non-Hispanic white children. Morbidity rates are even more likely than non-Hispanic white children to die of asthma. The cause of this striking health disparity is not clearly understood. However, discrimination and exposure to environmental pollutants and lack of adequate access to health care and health care resources are more frequently experienced by African American and Hispanic communities. However, microbiome has not been able to fully explain observed disparities. Genetic variation is associated with differences in disease pathophysiology and treatment response between racial/ethnic groups. However, race itself as social construct and genetic risk related to race also cannot explain the entirety of observed differences in disease prevalence and outcomes. The contributions to asthma risk and disparities in outcomes are interfunctional and include various compositional related to being a minority group in the United States. Multifactorial contributions to asthma-related health disparities have previously been identified as early life stress experienced (ACE) and toxic/chronic environmental exposures (AEU), abuse, housing, neighborhood stress, and experiencing racial discrimination factors that have been associated with asthma in adults. Chronic toxic stressors are also frequent among children experiencing toxic stress who may be suffering not only through exposure to toxic stress but also through long-term physiological pathways such as the hypothalamic-pituitary-adrenal axis and cortisol production and asthma pathophysiology and disease control between ACE/chronic stressors and asthma risk, as described above in adult and pediatric populations. Our study suggests that these disparities exist in early childhood, when interventions to prevent them may be more effective.

Action Steps

• 1st! Examine societal barriers to equitable opportunities for health
  • Addressing structural and institutional racism- historical and compounded current impacts
  • Ask patients about potential environmental impacts on their day to day lives
  • “Federal agencies are directed to identify and address disproportionately adverse human health or environmental effects of policies on “minority and low-income populations,” which define the “socially vulnerable”

Conclusions

• Asthma/allergy related health disparities are well-known and described
• Inequities in where one “lives, works, plays” are major contributors to asthma/allergy related disparities
• Institutional racism within past and current policies and practices continue to lead to disproportionately impacted communities
• Environmental justice must begin with addressing the overlapping effects of structural and systemic racism within society

Thank you

TABLE Practical recommendations for integrating climate change into the flow of pediatric primary care visits.

<table>
<thead>
<tr>
<th>Climate-related</th>
<th>Practical screening questions, suggested climate conservation actions, recommendations and resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health and safety</td>
<td>Climate change affects people of all ages, but some groups are more at risk. Disrupt global food supply chains, and may increase the number of patients facing food insecurity.</td>
</tr>
<tr>
<td>3. The last 12 months, have you worried you would run out of food before you had money to buy more?</td>
<td></td>
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<tr>
<td>4. Did you receive a vegetable or fruit at your local community garden?</td>
<td></td>
</tr>
<tr>
<td>Water issues and safety</td>
<td>Climate change makes severe floods and droughts more likely and prompts waterborne disease outbreaks.</td>
</tr>
<tr>
<td>3. Bottled water contributes to pollution and the climate crisis, is not generally safer, and lacks fluoride.</td>
<td></td>
</tr>
<tr>
<td>Housing security and housing problems</td>
<td>Those without shelter face exceptional risks from extreme weather.</td>
</tr>
<tr>
<td>3. Exposure to mold or extreme heat in their home, can cause respiratory and allergic reactions.</td>
<td></td>
</tr>
<tr>
<td>Energy security</td>
<td>More extreme weather contributes to power outages, increased costs of energy bills, and generation using fossil fuels.</td>
</tr>
<tr>
<td>3. Extreme heat or cold-related illnesses.</td>
<td></td>
</tr>
<tr>
<td>Depression screening</td>
<td>Climate change, disasters, and displacement can compromise mental health and result in stress for children and caregivers.</td>
</tr>
</tbody>
</table>

Philipsborn et al Curr Probl Pediatr Adolesc Health Care, June 2021
• Viral data from Raj