Climate Change

Climate change refers to any significant change in climate variables including temperature, precipitation, or wind that lasts for decades or longer. It may include changes in variability of average weather conditions or extreme weather conditions. Both human activities and natural factors contribute to climate change. Human activities, such as burning fossil fuels; cutting down forests; and developing land for farms, cities, and roads, release heat-trapping greenhouse gases into the atmosphere. Natural causes, such as changes in the Earth's orbit, the sun's intensity, the circulation of the ocean and the atmosphere, and volcanic activity, contribute to climate change in a variety of ways.[1]

Climate change may increase children's exposure to extreme temperatures, polluted air and water, extreme weather events, wildfires, infectious disease, allergens, pesticides, and other chemicals. These exposures may affect children's health in a number of direct and indirect ways. It is important to note that climate change will likely result in a mix of both positive and negative health impacts. For example, warmer summers may increase the number of heat-related injuries and deaths, while warmer winters may result in fewer cases of cold-related injuries and deaths.[2] The effects of climate change will also vary from one location to another and will likely change over time as climate change continues.[2,3] Furthermore, the human health risks from climate change may be affected strongly by changes in health care advances and accessibility, public health infrastructure, and technology.[2,4-6]

Direct effects of extreme temperatures are one area of concern, as climate change is expected to increase the number and intensity of hot days, hot nights, and heat waves in the United States.[5,7,8] Heat exposure can result in heat rashes, heat stroke, heat exhaustion, and even death; children may be especially at risk because they often spend more time outside than adults do.[2,9] Children's bodies are less effective at adapting to heat compared with those of adults.[10] Also, children may not feel the need to drink as urgently, which can lead to severe dehydration and electrolyte imbalance.[10,11] Humidity can further exacerbate heat stress in children.[10,11] Infants may be especially vulnerable to heat events in part because they depend on adults for care and are unable to communicate thirst and discomfort.[6,12,13] Caregivers can help protect children from heat-related health effects.[14]

Many factors can modify the impact of heat exposure, including geographic location, income level, and the built environment.[15] Studies have shown that the temperature at which mortality and morbidity (e.g., respiratory hospital admissions) can occur from heat exposure varies based on location.[16-18] Extreme heat exposure may have a greater impact on populations living in regions that experience high temperatures less frequently, such as the Northwest and Midwest United States. In warmer climates such as those in the South and Southwest United States, the population may be acclimated to heat and area infrastructure is better designed to accommodate high temperatures.[13,19] A higher income allows families to adapt more easily to meet the challenges of climate change compared with lower-income families, because they can

afford the use of air conditioners and other cooling methods to create a more ideal and comfortable environment.[3]

The urban built environment can both exacerbate and alleviate the effects of heat. For example, high concentrations of buildings in urban areas cause what is known as the urban heat island effect: generating as well as absorbing and releasing heat, resulting in urban centers that are several degrees warmer than surrounding areas. Expanding the area of parks and green spaces and increasing the density of trees in and around cities can help to reduce this effect.[6]

Warmer winters may have the effect of decreasing the number of cold-related deaths and injuries.[2,15] It is difficult to estimate the net changes in mortality due to climate change; however, a recent assessment by the United States Global Change Research Program concluded that increases in heat-related mortality due to climate change are unlikely to be compensated by decreases in cold-related mortality.[8]

High temperatures, heat waves, and associated stagnant air masses can increase levels of air pollution, specifically ground level ozone, fine particulate matter ($PM_{2.5}$), nitrogen oxides, and sulfur oxides.[2,6,8,9] These air pollutants can be harmful for children: they may contribute to the development of new cases of asthma, aggravate preexisting cases of asthma, cause decrements to lung function, increase respiratory symptoms such as coughing and wheezing, and increase hospital admissions and emergency room visits for respiratory diseases.[20-35] Because children may spend a lot of time outdoors, often while exerting themselves for sports or play, they can be especially vulnerable to the impacts of poor air quality.[8]

Climate change is likely to change the timing, frequency, and intensity of extreme weather events, including heat waves, hurricanes, heavy rainfall, droughts, high coastal waters, and storm surges.[5,36] These events can cause traumatic injury and death, as well as emotional trauma. Extreme weather events are also associated with increased risk of food- and water-borne illnesses as sanitation, hygiene, and safe food and water supplies are often compromised after these types of events.[2] One study found that periods of heavy rainfall were associated with increased emergency room visits for gastrointestinal illness among children.[37] Heavy rainfall may result in flooding, which can lead to contamination of water with dangerous chemicals, heavy metals, or other hazardous substances from storage containers or from preexisting chemical contamination already in the environment.[2,36] Elevated temperatures and low precipitation are also projected to increase the size and severity of wildfires. This can lead to increased eye and respiratory illnesses and injuries, which include burns and smoke inhalation.[2] Extreme weather events can be especially dangerous for children because they are dependent on adults for care and protection.[7]

A number of infectious diseases may be affected by climate change. The combined effects of increased temperature and precipitation are projected to cause increases in some water-, food-, and vector-borne illnesses. In general, increased temperature results in higher replication, transmission, persistence, habitat range, and survival of bacterial pathogens (the effect on viral pathogens is less clear), and produces a greater number of water- and food-borne parasitic

infections.[5,6,8] Climate change is also expected to expand or shift the habitat and range of disease-carrying organisms, such as mosquitoes, ticks, and rodents.[5] Changes in the geographic distribution of disease-carrying organisms may alter the spread of vector-borne diseases such as Lyme disease, West Nile virus and Dengue fever.[5] Children may be at greater risk for these types of infectious diseases as they spend more time outdoors compared with adults, where they might contact disease-carrying organisms, and they have less-developed immune systems.[14]

Climate change, including changes in carbon dioxide (CO_2) concentrations and temperature, may affect the growth and distribution of allergen-producing vegetation such as weeds, grasses, and trees. Climate change has already caused an earlier onset of the U.S. spring pollen season and a lengthened ragweed season.[15,38] The aeroallergens (e.g., pollen) themselves might be changed in terms of production, distribution, dispersion, and allergic potency.[2,6,15] Exposure to weed and grass pollen has been associated with exacerbation of children's asthma, emergency room visits, and hospitalizations.[39-41]

Through various indirect pathways, climate change may lead to increasing levels and/or frequencies of childhood exposure to harmful contaminants.[6,14] Changes in temperature, rainfall, and crop practices related to climate change are likely to affect exposure to pathogens, pesticides, and other chemicals in a number of ways. Broader geographic distribution of pests and increased growth of invasive weeds will likely lead to greater use of pesticides.[6,8] Increased precipitation and increased variability in precipitation are likely to increase pathogen and contaminant levels in lakes and other surface waters.[2,42] The distribution of chemicals in the environment is likely to change: for example, an increase in ice melts caused by a warming climate may release some past emissions of globally transported chemicals, such as polychlorinated biphenyls (PCBs) and mercury, that have been trapped in polar ice.[43,44] Increasing concentrations of these chemicals in the atmosphere, and subsequent deposition to land and water, have the potential to increase concentrations of these chemicals in fish and other foods derived from animals. Warmer water temperatures may also increase the release of chemical contaminants from sediments, increasing their uptake in fish.[2] Climate change may result in children spending more time indoors. Buildings that are tightly sealed in response to adverse weather conditions may result in increased exposure to contaminants from poor ventilation and higher concentrations of indoor pollutants such as radon, environmental tobacco smoke, and formaldehyde.[45]

Children are expected to be especially sensitive to the effects of climate change for a number of reasons. Young children and infants are particularly vulnerable to heat-related illness and death.[6] Compared with adults, children have higher breathing rates, spend more time outside, and have less developed respiratory tracts—all making children more sensitive to air pollutants. Additionally, children have immature immune systems, meaning that they can experience more serious impacts from infectious diseases.[8] The greatest impacts are likely to fall on children in poor families, who lack the resources, such as adequate shelter and access to air conditioning, to cope with climate change.[8]

EPA is currently developing a new children's environmental health indicator for climate change. The new indicator will focus on the frequency of extreme heat events over time. EPA intends to complete development of this new indicator in 2014, and it will be made available at www.epa.gov/ace when completed.

Environments and Contaminants

Climate Change

1. U.S. Environmental Protection Agency. 2010. *Climate Change Science Facts*. Washington, DC: U.S. EPA, Office of Air and Radiation. EPA 430-F-10-002. http://www.epa.gov/climatechange/downloads/Climate_Change_Science_Facts.pdf.

2. U.S. Environmental Protection Agency. 2009. *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202 (a) of the Clean Air Act*. Washington, DC: U.S. EPA, Office of Atmospheric Programs, Climate Change Division. http://epa.gov/climatechange/Downloads/endangerment/Endangerment_TSD.pdf.

3. U.S. Global Change Research Program. 2008. *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems (SAP 4.6)*. Washington, DC: U.S. Environmental Protection Agency. http://downloads.climatescience.gov/sap/sap4-6/sap4-6-final-report-all.pdf.

4. Field, C.B., L.D. Mortsch, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott. 2007. North America. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson. Cambridge, UK: Cambridge University Press, 617-652.

5. National Research Council. 2010. Advancing the Science of Climate Change. In *America's Climate Choices*. Washington, DC: The National Academies Press.

6. The Interagency Working Group on Climate Change and Health. 2010. *A Human Health Perspective on Climate Change*. Research Triangle Park, NC: Environmental Health Perspectives/National Institute of Environmental Health Sciences. http://www.niehs.nih.gov/health/assets/docs_a_e/climatereport2010.pdf.

7. U.S. Environmental Protection Agency. 2009. *Climate Change and Children's Health*. Washington, DC: U.S. EPA, Office of Children's Health Protection. EPA-100-K-09-008. http://yosemite.epa.gov/ochp/ochpweb.nsf/content/OCHP_Climate_Brochure.htm/$File/OCHP_Climate_Brochure.pdf.

8. U.S. Global Change Research Program. 2009. *Global Climate Change Impacts in the United States*. Edited by T. R. Karl, J. M. Melillo and T. C. Peterson. Cambridge, UK: Cambridge University Press. http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf.

9. Shea, K.M. 2007. Global climate change and children's health. *Pediatrics* 120 (5):1149-52.

10. Committee on Sports Medicine and Fitness. 2000. Climatic heat stress and the exercising child and adolescent: American Academy of Pediatrics policy statement. *Pediatrics* 106:158-9.

11. Knowlton, K., M. Rotkin-Ellman, G. King, H.G. Margolis, D. Smith, G. Solomon, R. Trent, and P. English. 2009. The 2006 California heat wave: Impacts on hospitalizations and emergency department visits. *Environmental Health Perspectives* 117 (1):61-7.

12. Basu, R., and B.D. Ostro. 2008. A multicounty analysis identifying the populations vulnerable to mortality associated with high ambient temperature in California. *American Journal of Epidemiology* 168 (6):632-637.

13. U.S. Environmental Protection Agency. 2006. *Excessive Heat Events Guidebook*. Washington, DC: U.S. EPA, Office of Atmospheric Programs. EPA 430-B-06-005. http://www.epa.gov/heatisld/about/pdf/EHEguide_final.pdf.

14. Sheffield, P.E., and P.J. Landrigan. 2011. Global climate change and children's health: threats and strategies for prevention. *Environmental Health Perspectives* 119 (3):291-8.

15. Confalonieri, U., B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revich, and A. Woodward. 2007. Human Health. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson. Cambridge, UK: Cambridge University Press, 391-431.

16. Baccini, M., A. Biggeri, G. Accetta, T. Kosatsky, K. Katsouyanni, A. Analitis, H.R. Anderson, L. Bisanti, D. D'Ippoliti, J. Danova, et al. 2008. Heat effects on mortality in 15 European cities. *Epidemiology* 19 (5):711-9.

17. Curriero, F.C., K.S. Heiner, J.M. Samet, S.L. Zeger, L. Strug, and J.A. Patz. 2002. Temperature and mortality in 11 cities of the eastern United States. *American Journal of Epidemiology* 155 (1):80-87.

18. Ye, X., R. Wolff, W. Yu, P. Vaneckova, X. Pan, and S. Tong. 2011. Ambient temperature and morbidity: A review of epidemiological evidence. *Environmental Health Perspectives* 120 (1):19-28.

19. O'Neill, M.S., and K.L. Ebi. 2009. Temperature extremes and health: Impacts of climate variability and change in the United States. *Journal of Occupational and Environmental Medicine* 51 (1):13-25.

20. Agency for Toxic Substances and Disease Registry. 1998. *Toxicological Profile for Sulfur Dioxide*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. www.atsdr.cdc.gov/toxprofiles/tp116-c2.pdf.

21. Andersen, Z.J., P. Wahlin, O. Raaschou-Nielsen, T. Scheike, and S. Loft. 2007. Ambient particle source apportionment and daily hospital admissions among children and elderly in Copenhagen. *Journal of Exposure Science and Environmental Epidemiology* 17 (7):625-36.

Climate Change (continued)

22. Annesi-Maesano, I., D. Moreau, D. Caillaud, F. Lavaud, Y. Le Moullec, A. Taytard, G. Pauli, and D. Charpin. 2007. Residential proximity fine particles related to allergic sensitisation and asthma in primary school children. *Respiratory Medicine* 101 (8):1721-9.

23. Gauderman, W.J., G.F. Gilliland, H. Vora, E. Avol, D. Stram, R. McConnell, D. Thomas, F. Lurmann, H.G. Margolis, E.B. Rappaport, et al. 2002. Association between air pollution and lung function growth in southern California children: Results from a second cohort. *American Journal of Respiratory and Critical Care Medicine* 166 (1):76-84.

24. Gent, J.F., E.W. Triche, T.R. Holford, K. Belanger, M.B. Bracken, W.S. Beckett, and B.P. Leaderer. 2003. Association of low-level ozone and fine particles with respiratory symptoms in children with asthma. *Journal of the American Medical Association* 290 (14):1859-67.

25. Karr, C.J., P.A. Demers, M.W. Koehoorn, C.C. Lencar, L. Tamburic, and M. Brauer. 2009. Influence of ambient air pollutant sources on clinical encounters for infant bronchiolitis. *American Journal of Respiratory and Critical Care Medicine* 180 (10):995-1001.

26. McConnell, R., T. Islam, K. Shankardass, M. Jerrett, F. Lurmann, F. Gilliland, J. Gauderman, E. Avol, N. Kuenzli, L. Yao, et al. 2010. Childhood incident asthma and traffic-related air pollution at home and school. *Environmental Health Perspectives* 118:1021-26.

27. Mortimer, K., R. Neugebauer, F. Lurmann, S. Alcorn, J. Balmes, and I. Tager. 2008. Air pollution and pulmonary function in asthmatic children: Effects of prenatal and lifetime exposures. *Epidemiology* 19 (4):550-7.

28. Norris, G., S.N. YoungPong, J.Q. Koenig, T.V. Larson, L. Sheppard, and J.W. Stout. 1999. An association between fine particles and asthma emergency department visits for children in Seattle. *Environmental Health Perspectives* 107 (6):489-93.

29. Ostro, B., L. Roth, B. Malig, and M. Marty. 2009. The effects of fine particle components on respiratory hospital admissions in children. *Environmental Health Perspectives* 117 (3):475-80.

30. Romieu, I., F. Meneses, S. Ruiz, J.J. Sienra, J. Huerta, M.C. White, and R.A. Etzel. 1996. Effects of air pollution on the respiratory health of asthmatic children living in Mexico City. *American Journal of Respiratory and Critical Care Medicine* 154 (2 Pt 1):300-7.

31. Tang, C.S., L.T. Chang, H.C. Lee, and C.C. Chan. 2007. Effects of personal particulate matter on peak expiratory flow rate of asthmatic children. *The Science of the Total Environment* 382 (1):43-51.

32. U.S. Environmental Protection Agency. 2006. *Air Quality Criteria for Ozone and Related Photochemical Oxidants*. Research Triangle Park, NC: U.S. EPA, National Center for Environmental Assessment. EPA/600/R-05/004aF. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=149923.

33. U.S. Environmental Protection Agency. 2008. *Integrated Science Assessment for Oxides of Nitrogen--Health Criteria*. Research Triangle Park, NC: U.S. EPA. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=194645.

34. U.S. Environmental Protection Agency. 2009. *Integrated Science Assessment for Particulate Matter (Final Report)*. Washington, DC: U.S. EPA, National Center for Environmental Assessment. EPA/600/R-08/139F. http://cfpub.epa.gov/ncea/CFM/recordisplay.cfm?deid=216546.

35. Villeneuve, P.J., L. Chen, B.H. Rowe, and F. Coates. 2007. Outdoor air pollution and emergency department visits for asthma among children and adults: A case-crossover study in northern Alberta, Canada. *Environmental Health* 6:40.

36. Intergovernmental Panel on Climate Change. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press. http://www.ipcc-wg2.gov/SREX/images/uploads/SREX-All_FINAL.pdf.

37. Drayna, P., S.L. McLellan, P. Simpson, S.H. Li, and M.H. Gorelick. 2010. Association between rainfall and pediatric emergency department visits for acute gastrointestinal illness. *Environmental Health Perspectives* 118 (10):1439-43.

38. Ziska, L., K. Knowlton, C. Rogers, D. Dalan, N. Tierney, M.A. Elder, W. Filley, J. Shropshire, L.B. Ford, C. Hedberg, et al. 2011. Recent warming by latitude associated with increased length of ragweed pollen season in central North America. *Proceedings of the National Academy of Sciences* 108 (10):4248-51.

39. Héguy, L., M. Garneau, M.S. Goldberg, M. Raphoz, F. Guay, and M.F. Valois. 2008. Associations between grass and weed pollen and emergency department visits for asthma among children in Montreal. *Environmental Research* 106 (2):203-11.

40. Schmier, J.K., and K.L. Ebi. 2009. The impact of climate change and aeroallergens on children's health. *Allergy and Asthma Proceedings* 30 (3):229-37.

41. Ziska, L.H., P.R. Epstein, and C.A. Rogers. 2008. Climate change, aerobiology, and public health in the northeast United States. *Mitigation and Adaptation Strategies for Global Change* 13:607-613.

42. U.S. Environmental Protection Agency. 2009. *Climate Change: Water Resources*. U.S. EPA, Climate Change Division. Retrieved February 11, 2011 from http://www.epa.gov/climatechange/effects/water/index.html.

43. Bogdal, C., P. Schmid, M. Zennegg, F.S. Anselmetti, M. Scheringer, and K. Hungerbuhler. 2009. Blast from the past: Melting glaciers as a relevant source for persistent organic pollutants. *Environmental Science and Technology* 43 (21):8173-7.

44. Carrie, J., F. Wang, H. Sanei, R.W. Macdonald, P.M. Outridge, and G.A. Stern. 2010. Increasing contaminant burdens in an Arctic fish, Burbot (Lota lota), in a warming climate. *Environmental Science and Technology* 44 (1):316-322.

Climate Change (continued)

45. Institute of Medicine. 2011. *Climate Change, the Indoor Environment, and Health*. Washington, DC: The National Academies Press. http://www.nap.edu/catalog.php?record_id=13115.