American Academy of Pediatrics
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TECHNICAL REPORT

Global Climate Change and Children's Health

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ABSTRACT

There is a broad scientific consensus that the global climate is warming, the process is accelerating, and that human activities are very likely (>90% probability) the main cause. This warming will have effects on ecosystems and human health, many of them adverse. Children will experience both the direct and indirect effects of climate change. Actions taken by individuals, communities, businesses, and governments will affect the magnitude and rate of global climate change and resultant health impacts. This technical report reviews the nature of the global problem and anticipated health effects on children and supports the recommendations in the accompanying policy statement on climate change and children's health.

INTRODUCTION

Scientists[1] and governments[2] concur that Earth is warming; rapid global climate change is underway, and human activities are very likely (>90% probability) the main cause. Adverse human health and ecosystem consequences are anticipated,[3] and some are already being measured. Physicians have written on the projected effects of climate change on public health,[4,5] but little has been written specifically about anticipated effects of climate change on children's health.[6]

Children represent a particularly vulnerable group that is likely to suffer disproportionately from both direct and indirect adverse health effects of climate change.[7] Pediatric health care professionals must understand the escalating nature of these threats, anticipate their effects on children's health, and participate as children's advocates for strong mitigation and adaptation strategies now and at all levels, from local to global.[8] This technical report examines both direct and indirect threats to children's health and futures related to climate change.*

NATURE OF THE GLOBAL PROBLEM

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperature, widespread melting of snow and ice, and rising global mean sea level."[1] According to the National Climatic Data Center, all records indicate that during the past century, global surface temperatures have increased at a rate near 0.6°C per century (1.1°F per century), but the trend has been 3 times larger since 1976.[9] The results of this warming on regional climate are not uniform. In general, land-surface temperatures are increasing faster than sea-surface temperatures.[9] The climate in latitudes between 40°N and 70°N is warming more quickly than that in lower latitudes, and some areas (eg, the southeastern United States) are actually cooling. Changes in precipitation that occur with climate change

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*Since the writing of this technical report, the full reports of the 4th Assessment by the Intergovernmental Panel on Climate Change have become available, and additional studies have been published that include more detailed historical and current data documenting global climate change.

All technical reports from the American Academy of Pediatrics automatically expire 5 years after publication unless reaffirmed, revised, or retired at or before that time.

The guidance in this report does not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

Key Words
climate change, global warming, child, pediatric, health, sustainable development

Abbreviation
GHG—greenhouse gas

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are also nonuniform.[10] Since 1900, precipitation has increased 5% globally, but it has increased 0.5% to 1% per decade in northern midlatitudes and decreased 0.3% per decade in subtropical latitudes.[11] In contrast, snowfall in the northern hemisphere has decreased by 10% since 1966.[11]

Examples of the effects of climate change have been widely reported.[11] Glaciers are in rapid retreat, and Arctic sea ice is melting.[12] As a result of thermal expansion, sea level has increased 1 to 2 mm/year over the past 100 years.[11] Oceans are acidifying as atmospheric carbon dioxide (CO_2) is absorbed by the marine buffer system.[13] Ecosystems and individual species are being affected in a variety of ways.[14] Changes in temperature affect the density and range of species; natural history traits such as migration, flowering, and egg laying; morphology such as body size and behavior; and genetic frequency shifts. In an analysis of 143 studies that span decades of observation,[15] more than 80% of 1468 species (mollusks to mammals and grasses to trees) are currently showing significant changes in temperature-sensitive species traits.

There is strong consensus among expert scientists that Earth is undergoing rapid, global climate change,[1,16] although there remains uncertainty about how rapidly and extensively the climate will change in the future. Given the range of possibilities, the Intergovernmental Panel on Climate Change has developed a suite of scenarios for different levels of mitigation and adaptation in response to anthropogenic (man-made) global climate change; all their cases predict that temperatures and sea level will continue to rise throughout the 21st century.[17] Recent analyses describe thermal inertia in Earth's climate system such that even if greenhouse gas (GHG) emissions were abruptly reduced to zero, the planet would continue to warm for decades until the energy stored in the system equilibrates.[18] The possibility of reaching a tipping point at which abrupt, large, and irreversible change could be superimposed on current trends adds both urgency and further ambiguity to the situation.[19] In this context, it is critical to understand that current human activities are accelerating climate change and that future human activities will affect their trajectories.[20]

ANTHROPOGENIC CAUSES OF THE CHANGE

The greenhouse effect is necessary to life on Earth as we know it (Fig 1). Without heat-trapping GHGs such as water vapor, CO_2, and other natural components of the atmosphere, Earth would be a lifeless, frozen planet (average temperature: −18°C) instead of the diverse biosphere we know today.[11] Since the onset of the industrial age, however, human activity has dramatically enhanced the greenhouse effect by rapidly adding large amounts of GHGs to the atmosphere (Table 1 [note that the United States leads total country and per-capita emissions]). Three GHGs, CO_2, methane, and nitrous oxide, are responsible for approximately 88% of the anthropogenic influences that enhance the greenhouse effect and have increased 35%, 155%, and 18%, respectively, since 1750 (the beginning of the industrial era).[21] Rates of increase in GHGs are accelerating, up 20% since 1990.

CO_2 is the most important GHG and is responsible for more than 60% of human-enhanced increases and more than 90% of rapid increase in the past decade.[21] Most CO_2 emissions are from the burning of fossil fuels such as coal, oil, and gas. Rising CO_2 is also related, to a lesser extent, to deforestation, which eliminates an important carbon sink (carbon sinks are reservoirs that absorb or take up released carbon from another part of the carbon cycle; the 4 major sinks on the planet are the atmo-

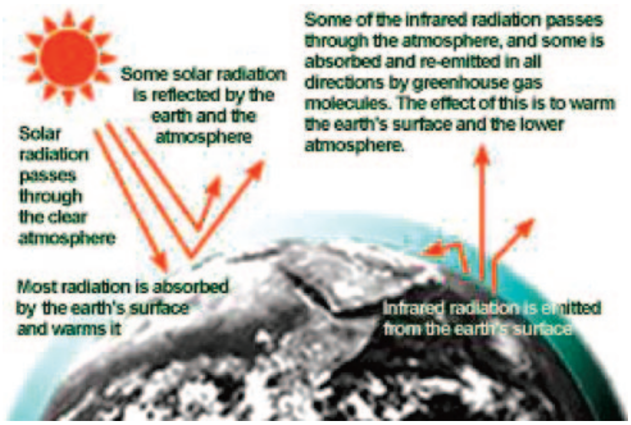

FIGURE 1
The greenhouse effect. Energy from the sun drives Earth's weather and climate and heats its surface; in turn, the earth radiates energy back into space. Atmospheric greenhouse gases (water vapor, CO_2, and other gases) trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse. Without this natural "greenhouse effect," temperatures would be much lower than they are now, and life as known today would not be possible. Instead, thanks to GHGs, Earth's average temperature is a more hospitable 60°F. However, problems may arise when the atmospheric concentration of GHGs increases. (Source: US Environmental Protection Agency [http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html].)

TABLE 1 2004 Carbon Dioxide Emissions From Fossil Fuel

Region and Country[a]	Total Emissions, Million Metric Tons	Emissions Per Capita, Metric Tons
North America	6886.88	15.99
United States	5912.21	20.18
Central and South America	1041.45	2.35
Europe[b]	4653.43	7.96
Eurasia[b]	2550.75	8.88
Russia	1684.84	11.70
Middle East[b]	1319.70	7.24
Africa[b]	986.55	1.13
Asia and Oceania	9605.81	2.69
China	4707.28	3.62
India	1112.84	1.04
Japan	1262.10	9.91
World Total	27 043.57	4.24

[a] Itemized if country's emissions exceed 1000 million metric tons.
[b] No single country in the region exceeds 1000 million metric tons.
Source: Energy Information Administration (www.eia.doe.gov/environment.html).

sphere, the terrestrial biosphere [eg, trees and freshwater systems], oceans, and sediments).[21] Currently, the atmosphere contains approximately 370 ppm of CO_2, which is the highest concentration in 420 000 years and perhaps as long as 2 million years.[11] Estimates of CO_2 concentrations at the end of the 21st century range from 490 to 1260 ppm, or a 75% to 350% increase above preindustrial concentrations.[11]

The importance of the magnitude of GHG emissions is linked to the rate of release. In the distant geologic past, similar concentrations of atmospheric CO_2 have occurred, but they accumulated over a 10 000-year period, allowing for the slow, global biogeochemical cycles to adjust to the increases. Current emissions are being added to the atmosphere at 300 times this rate.[11] This confluence of speed and quantity of emissions has created the current, unprecedented rapid climate change.

CLIMATE CHANGE–ASSOCIATED HEALTH EFFECTS ON CHILDREN

Human health is affected by the condition of the physical environment.[22] Because of their physical, physiologic, and cognitive immaturity, children are often most vulnerable to adverse health effects from environmental hazards.[23] As the climate changes, environmental hazards will change and often increase, and children are likely to suffer disproportionately from these changes.[8] Anticipated health threats from climate change include extreme weather events and weather disasters, increases in certain infectious diseases, air pollution, and thermal stress. Within all of these categories, children have increased vulnerability compared with other groups. These direct health threats are discussed in this section, with an emphasis on children in the United States.[24] Indirect threats are discussed briefly in "Long-term and Indirect Climate Change-Associated Health Threats to Children" below.

Extreme Weather Events and Weather Disasters

The Intergovernmental Panel on Climate Change predicts that it is "likely" or "extremely likely" that climate change will cause increased frequency and intensity of extreme weather events and weather disasters.[25] Often, these events are categorized as floods, storms, and droughts. Floods represented 43% of weather-related disasters between 1992 and 2001 and are the most frequent weather-related disaster. Although less prevalent, droughts and their associated famines are the most deadly weather-related disasters.[3] Developed countries such as the United States have systematically increased the risk to populations from flood events by developing coastlines and flood plains. In the United States, hurricanes and tornadoes may be the most dramatic and visible weather disasters. Evidence suggests that the frequency of category 4 and 5 hurricanes has increased over the past 30 years, but the observation period is still too short to attribute this change to increased sea-surface temperature and climate change with high confidence.[26]

The health consequences associated with extreme weather events include death, injury, increases in infectious diseases, and posttraumatic mental health and behavior problems.[27] Few studies have specifically examined such consequences in children. Globally, 66.5 million children annually were affected by disasters between 1990 and 2000.[28] Children everywhere are at risk of injury and death from storms and floods.[29] In the developed world, infectious disease outbreaks follow natural disasters when sanitation, sewage treatment, and water-purification plants become damaged or overwhelmed, refrigeration and cooking facilities are disrupted, and people are unusually crowded in temporary shelter. These outbreaks are usually mild and well controlled, which is in contrast to the aftermath of similar catastrophes in developing nations, where disease outbreaks can be deadly.[24] Mosquito-borne and other vector-borne illnesses may also be increased when storms or floods create large amounts of standing water suitable for breeding. Mental and emotional distress documented for children and adolescents after weather disasters include posttraumatic stress disorder and high rates of sleep disturbance, aggressive behavior, sadness, and substance use/abuse.[29] Some studies have suggested that children have more persistent symptoms than adults who experience the same disaster,[30] but more studies specific to children's experience are required.[31] Community support services[32] and early therapeutic intervention and postdisaster counseling[33,34] can significantly reduce the medium- and long-term mental health burden on children. Experiences with Hurricane Katrina demonstrated the difficulties with tracking children's whereabouts, keeping children and caregivers together, and special needs of hospitalized infants and children during and after major natural disasters.[35]

Infectious Diseases

Globally, infectious diarrhea is the second-leading cause of death in young children; water-borne gastroenteritis is projected to increase under conditions of global warming. Currently, the World Health Organization estimates that, approximately 1.62 million children younger than 5 years die of diarrhea annually, and most cases are attributable to contaminated water.[36] Although children in developed countries are unlikely to die of water-borne infections, they may suffer illness that is attributable indirectly to climate change. Events associated with El Nino serve as a model for global warming by altering weather for periods of several years in the direction of a hotter climate. During El Nino events, rates of hospitalizations of children for diarrhea increase.[37] (In 1 study, the rate of hospitalizations of children for diarrhea increased 8% per degree centigrade of temperature increase.[38]) Water-borne disease outbreaks in the United

States exhibit a positive correlation with excess precipitation events, which are likely to increase with climate change; over a 45-year period, 68% of water-borne illness outbreaks have been associated with precipitation above the 80th percentile.[39] Foodborne illness correlates positively with ambient temperature and is also likely to increase as the climate warms.[37,40,41]

Vector-borne infections are affected by climate change.[42] Both the hosts (eg, rodents, insects, snails) and the pathogens (eg, bacteria, viruses, parasites) can be sensitive to climatic variables such as temperature, humidity, and rainfall. The ability to predict disease rates related to climate change is complicated by a large number of additional variables such as topography, land use, urbanization, human population distribution, level of economic development, and public health infrastructure.[43] There is no easy formula that predicts climate change–related infection risk with confidence.

Malaria is a climate-sensitive vector-borne illness to which children are particularly vulnerable. According to the World Health Organization, malaria currently causes 350 million to 500 million illnesses annually and more than 1 million deaths.[44] Because they lack specific immunity, children experience disproportionately high levels of both morbidity and mortality from malaria; 75% of malaria deaths occur in children younger than 5 years. The young are also more susceptible to cerebral malaria, which can lead to lifelong neurologic damage in those who survive. In areas of sub-Saharan Africa, the death rate from malaria in children 0 to 4 years of age is 9.4 in 1000 vs 0.13 in 1000 in those older than 14 years.[45] More than 3 billion people live in malaria-prone areas today. Climate change is expanding the range of host mosquitoes to higher altitudes and higher latitudes, and warmer temperatures speed the development of the parasite within the host vector.[46] Small children will be most affected by the expansion of malaria zones and the success or failure of societal response to this change.

Three vector-borne diseases that affect the United States illustrate ways in which climate change can enhance disease burden: West Nile virus infection, Lyme disease, and hantavirus pulmonary syndrome.

West Nile virus infection was first reported in the United States in New York in 1999. Although it is still not known how it entered the United States, once introduced, it spread rapidly. A series of warm winters failed to kill the mosquito vectors. Warmer summers amplified the life cycle of the mosquitoes and increased the viral load. Drought and rain cycles, particularly as they affected urban landscapes, increased the contact of the bridging mosquito vectors with birds and humans.[46] Human populations with no herd immunity were highly susceptible to infection. In 1999, there were 62 human cases of West Nile virus infection, all reported from New York state. In 2003, there were 9862 human cases reported from 45 states and the District of Columbia.[47] Although this infection is primarily of concern for the elderly rather than children, the rapid spread illustrates the challenge of infection control in a warming climate.

The prevalence of Lyme disease has been increasing in the United States since it became a reportable disease in 1992.[48] The geographic distribution of *Ixodes* species ticks, the vectors for this bacterial infection, is expanding as well. Researchers in Sweden have documented a correlation between the expanding range for *Ixodes* ticks and climate change.[49] Children 5 to 14 years of age and adults 50 to 59 years of age are most likely to contract the illness. Lyme disease, although rarely fatal, occasionally causes long-term morbidity and represents another example of a disease that is likely to increase further as the climate warms.

Finally, the 1993 outbreak of hantavirus pulmonary syndrome in the southwest United States has been linked to the El Nino conditions of 1991–1992, with increased rainfall and pine nut production, which favored population growth among rodent vectors.[50] With a case fatality rate of 36%,[51] it is of concern that warmer climates may enhance vector populations further. As with most infectious diseases, human adaptations can reduce exposure risk and disease burden.[52]

Ambient Air Pollution

Air pollution is well established as a short-term contributor to hospital use[53] and premature death. Air pollutants such as fine particulates, nitrogen oxides, sulfur oxides, and ozone are likely to increase as countries adapt to hotter temperatures by using more energy to drive air conditioning and fans. The anticipated global population of 9 billion by 2050 will also be associated with increased energy demands, which, if met by burning more fossil fuels, will exacerbate both ambient air pollution and GHG emissions.[54] Children are especially vulnerable to both short-term illness and long-term damage from ambient air pollution, because their lungs are developing and growing, they breathe at a higher rate than adults, and they spend more time outdoors engaging in vigorous physical activity.[55] Air pollution (such as ozone and particulate matter) causes respiratory and asthma hospitalizations, school absences, increased respiratory symptoms, and decrements in lung function.[55] Formation of ozone, in particular, is known to increase with increasing temperature, even without increases in the precursor primary pollutants (volatile organic hydrocarbons and oxides of nitrogen).[56] Children who are active in outdoor sports in communities with high ozone are at increased risk of developing asthma.[57] In addition, high levels of particulate matter and other copollutants affect the ability of children's lungs to grow regardless of history of asthma.[58] Rates of preterm births, low birth weight, and infant mortality are increased in communities with high levels of particulate air pollution.[55]

A second change that is being observed is the temperature-related increases in pollen production and other aeroallergens in some regions and some cities. Increased temperature causes increases in amounts of pollens produced by some plants[59] and can also affect spatial distribution and density of plants, fungi, and molds that produce aeroallergens.[60] To the extent that exposure to aeroallergens contributes to the incidence, prevalence, and severity of asthma, atopy, and other respiratory disease, climate change will affect the pattern of disease in children. Some investigators have argued that part of the current global increase in childhood asthma can be explained by increased exposure to aeroallergens driven by climate change.[61]

Thermal Stress

For all organisms, there exists a range of ideal temperature above and below which mortality increases. Humans are no exception, although temperature-mortality relationships vary significantly by latitude, climatic zone, and level of socioeconomic development.[3] As ambient temperatures increase, the frequency of heat waves will increase. It is expected that there will be fewer cold-related deaths in a warmer world,[62] but whether this will offset the expected increase in heat-related deaths is unknown. Populations that live in temperate climates, such as in the United States and Europe, are likely to be hard hit initially, because global warming is most dramatic in these latitudes and there has been little time for populations to acclimatize to changes in temperature. Observations on heat and mortality have been reported for decades[63] and have gained recent attention with the heat waves of 2003 in Europe[64] and of 2006 in Europe and North America.[63,65] Heat-related deaths and hospitalizations are most common in the elderly, especially if they are ill.[66,67] One study has found that infants and young children may represent a second, albeit smaller, higher-risk group,[68] but effects on children have not been studied adequately. In addition, children spend more time outside, especially playing sports in the heat of the afternoon, which puts them at increased risk of heat stroke and heat exhaustion.[69] Increased outdoor time during hot weather may also put children at increased risk of UV radiation–related skin damage, including basal cell carcinoma and malignant melanoma.[70] Some data indicate that heat-related mortality in the United States has decreased in recent years, in part associated with increasing percentage of homes with air conditioners.[71] It is currently unknown how effective adaptation and acclimatization will be in preventing excess heat-related deaths and illness.[72,73]

LONG-TERM AND INDIRECT CLIMATE CHANGE-ASSOCIATED HEALTH THREATS TO CHILDREN

Long-term and indirect effects on children's health from climate change will depend on how the climate continues to change over the next decades and what sorts of mitigation and adaptation strategies are adopted now.[17] How quickly and comprehensively GHG emissions can be stabilized and then reduced will have a significant effect on the rate and degree of warming, but even the most optimistic scenarios describe continued warming through the end of this century.[17] Food availability may be affected as land and ocean food-productivity patterns shift.[74] Water availability may change and become much reduced in some regions, including during summer in the snow run-off–dependent American west coast.[75] Coastal populations will be forced to move because of rises in sea level, and massive forced migrations, driven by abrupt climate change, natural disaster, or political instability over resource availability, are conceivable.[24] In addition, world population is expected to grow by 50% to 9 billion by 2050, which would place additional stress on ecosystem services and increase the demand for energy, fresh water, and food.[54] As these changes evolve, social and political institutions will need to respond with aggressive mitigation strategies and flexible adaptation strategies to preserve and protect public health, particularly for children.

MITIGATION AND ADAPTATION STRATEGIES

Strategies to address the effects of climate change, known as mitigation and adaptation, are concepts that parallel the focus on both primary and secondary prevention strategies in pediatric health care. These strategies are discussed briefly here. The prevention or minimization of the effects of climate change on children's health is beyond the control of an individual pediatrician. Yet, pediatricians can play important public roles as advocates by individual example and through community participation, political involvement, or collective advocacy at the local, state, and national levels.[76,77]

Broadly, mitigation policies (Table 2) for reduction of atmospheric GHG include reducing emissions through energy efficiency and use of renewable energy sources, increasing carbon sinks by forest preservation and reforestation, and development of GHG-capture and -sequestration technologies (carbon sequestration is the fixation of atmospheric CO_2 in a carbon sink through an active process). Adaptation involves developing public health strategies to minimize adverse health outcomes that are anticipated from climate change. These strategies include improved disease surveillance and reporting, improved weather forecasting and early warning systems, advanced emergency management and disaster-preparedness programs, development and dissemination of appropriate vaccines and medicines, and public health education and preparedness. Category-specific examples

TABLE 2 **Some Examples of Mitigation Strategies**

	International	National and State	Community	Business, Nonprofits, Professional Societies	Individuals
Reduce emissions and increase use of renewable energy sources	Impose carbon-emissions caps by treaty	Create GHG inventory	LEED certification of public buildings	Energy audit of office and work toward LEED certification[a]	Drive less, use public transport, carpool
	Support clean, renewable technologies in developing countries	Impose carbon-emissions caps at national and/or state level	Energy audits and renovations for all public buildings	Reward carpoolers or employees who use public transport or walk/bike to work	Use vehicles that get the highest gas mileage
	Support research, development, and use of clean, renewable fuels	Increase solar, wind, energy-efficient biofuels, and other renewable energy sources	Efficient lighting in public spaces	Promote energy conservation	Perform energy audit of home or business and make associated changes
	Promote energy conservation	Invest in research, development, and use of clean, renewable fuels	Reward businesses and home owners for energy efficiency	Buy Energy Star office equipment	Buy Energy Star appliances
		Raise corporate average fuel efficiency standards for vehicles	Maximize public transport, ticket idling cars, tax individual parking spaces, create bike lanes, and enforce high-occupancy vehicle lanes	Support telecommuting and flexible hours	Buy local foods
		Promote energy conservation	Develop sustainability awards	Video and teleconference meetings	Engage in energy-conservation efforts
		Augment public transportation options	Promote energy conservation	Consider buying carbon offsets for travel to meetings[b]	Switch to compact fluorescent bulbs
Increase (protect) sinks	Arrest deforestation	Identify, protect, and restore carbon sinks	Plant trees	Increase green space	Plant trees and shrubs
	Restore forests and wilderness	Protect national forests and wilderness areas	Reward construction of green roofs	Add plants and trees in parking areas	Support parks and greenways
			Build parks and green space		
Carbon trapping and sequestration	Support research and development	Support research and development	Support research and development	Support research and development	Support through personal investments

This information here is not exhaustive. Many strategies have been proposed and overlap among sectors. Additional information can be found at www.grida.no/climate/ipcc_tar/wg3/index.htm, http://epa.gov/climatechange/wycd/index.html, and www.princeton.edu/~cmi.

LEED indicates Leadership in Energy and Environmental Design.

[a] The LEED Green Building Rating System is a nationally accepted benchmark for the design, construction, and operation of high-performance green buildings. LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their building's performance. LEED promotes a whole-building approach to sustainability by recognizing performance in 5 key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality.

[b] Reduction of individual GHG production can be accomplished by buying carbon offsets whereby, in this principle, an individual or business can pay someone to reduce or remove GHG production in that company's name. For example, if a company agrees to buy 10 tons of carbon offsets, the seller guarantees that 10 fewer tons of GHG will enter the atmosphere.

can be found at www.grida.no/climate/ipcc_tar/wg2/646.htm#tab18-2. These adaptation strategies include policy and legislative actions, engineering responses, and personal behavior change.

Effective implementation of mitigation and adaptation strategies must involve actions from the global to local levels by governments, corporations, communities, and individuals. Furthermore, climate change is part of generalized global change, which includes population growth, land use, economic change, and evolving technology; all have effects on individual human and public health (Fig 2). Any solutions that address climate change must be developed within the context of overall sustainable development (the use of resources by the current generation to meet current needs while ensuring that future generations will be able to meet their needs). Protecting the health of current and future generations requires a fundamental shift in thinking for health professionals[78]; pediatricians, as advocates for children's health, can be leaders in a move away from a traditional focus on disease prevention to a broader, more integrated focus that encompasses sustainability as synonymous with health. Given the health implications for current and future generations of children, the disease-prevention role for pediatric health care professionals includes advocating for environmental sustainability.

SUMMARY

This technical report describes the broad scientific consensus that man-made climate change has begun

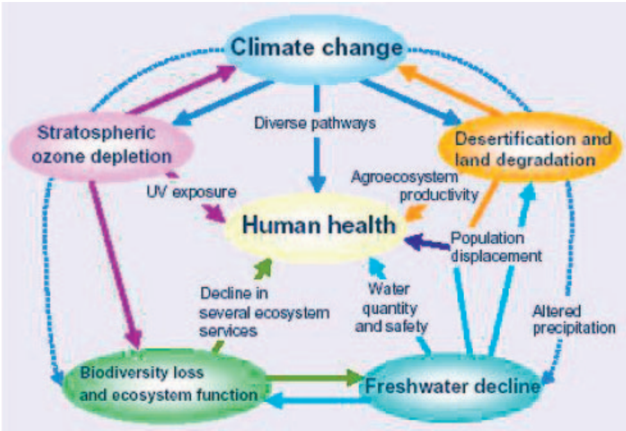

FIGURE 2
Global drivers that affect human health. Large-scale and global environmental hazards to human health include climate change, stratospheric ozone depletion, loss of biodiversity, changes in hydrological systems and the supplies of fresh water, land degradation, and stresses on food-producing systems. (Source: World Health Organization [www.who.int/globalchange/en/index.html].)

and is accelerating. The major cause of this change is the rapid release of CO_2 from burning of fossil fuel. All predictions indicate that climate change will continue for at least a century, but the trajectory of that change depends on human responses. There are anticipated effects on human health from extreme weather events, infectious diseases, air pollution, and heat stress. Although little research thus far has concentrated on the pediatric age group, it is likely that children will suffer disproportionately from climate change.[6] Furthermore, the state of the world of future children is uncertain and depends on actions taken to mitigate and adapt to climate change and other global-scale trends. Pediatric health care professionals are in an ideal position to advocate for action, not only to address climate change but also, more broadly, to ensure sustainability. Specific recommendations for pediatricians and governments are enumerated in the American Academy of Pediatrics policy statement[79] on climate change and children's health, which accompanies this technical report.

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REFERENCES

1. Intergovernmental Panel on Climate Change. Climate change 2007: the physical science basis—summary for policy makers. Available at: www.ipcc.ch/SPM2feb07.pdf. Accessed April 18, 2007
2. G8 Summit Documents. The Gleneagles communiqué: climate change, energy and sustainable development. Available at: www.fco.gov.uk/Files/kfile/PostG8_Gleneagles_Communique,0.pdf. Accessed April 18, 2007
3. McMichael AJ, Woodruff RE, Hales S. Climate change and human health: present and future risks. *Lancet.* 2006;367:859–869
4. Haines A, Patz JA. Health effects of climate change. *JAMA.* 2004;291:99–103
5. Epstein PR. Climate change and human health. *N Engl J Med.* 2005;353:1433–1436
6. Ebi KL, Paulson J. Climate change and children. *Pediatr Clin North Am.* 2007;54:213–226
7. United Nations Environment Programme, United Nations Children's Fund, World Health Organization. *Children in the New Millennium: Environmental Impact on Health*. Nairobi, Kenya: United Nations Environment Programme; 2002. Available at: www.unep.org/ceh. Accessed April 18, 2007
8. Shea K. Global environmental change and children's health: understanding the challenges and finding solutions. *J Pediatr.* 2003;143:149–154
9. National Climatic Data Center. Climate of 2005 annual review: temperature trends. Available at: www.ncdc.noaa.gov/oa/climate/research/2005/ann/global.html#Ttrends. Accessed April 18, 2007
10. Dore MH. Climate change and changes in global precipitation patterns: what do we know? *Environ Int.* 2005;31:1167–1181
11. National Climatic Data Center, National Oceanic and Atmospheric Administration. Global warming: frequently asked questions. Available at: www.ncdc.noaa.gov/oa/climate/globalwarming.html. Accessed April 18, 2007
12. Dowdeswell JA. The Greenland ice sheet and global sea-level rise. *Science.* 2006;311:963–964
13. The Royal Society. Ocean acidification due to increasing atmospheric carbon dioxide. London, England: The Royal Society; 2005. Available at: www.royalsoc.ac.uk/document.asp?id=3249. Accessed April 18, 2007
14. Board of the Millennium Ecosystem Assessment. Living beyond our means: natural assets and human well-being. Available at: www.maweb.org/en/BoardStatement.aspx. Accessed April 18, 2007
15. Root JL, Price JT, Hall KR, Schneider SH, Rosenzweig C, Pounds JA. Fingerprints of global warming on wild animals and plants. *Nature.* 2003;421:57–60
16. US Environmental Protection Agency. Climate change-science:

state of knowledge. Available at: www.epa.gov/climatechange/science/stateofknowledge.html. Accessed April 18, 2007
17. Intergovernmental Panel on Climate Change. Climate change 2001: synthesis report—summary for policymakers. Available at: www.ipcc.ch/pub/un/syreng/spm.pdf. Accessed April 18, 2007
18. Hansen J, Nazarenka L, Rudey R, et al. Earth's energy imbalance: confirmation and implications. *Science.* 2005;308:1431–1435
19. Schiermeier Q. A sea change. *Nature.* 2006;439:256–260
20. Hansen J, Sato M, Ruedy R, Lo K, Lea DW, Medina-Elizade M. Global temperature change. *Proc Natl Acad Sci U S A*. 2006;103:14288–14293
21. WMO World Data Centre for Greenhouse Gases. Greenhouse gas bulletin: the state of greenhouse gases in the atmosphere using global observations up to December 2004. Vol 1, March 14, 2006. Available at: http://gaw.kishou.go.jp/wdcgg/products/bulletin/Bulletin2004/wmo_bulletin_1.pdf. Accessed April 18, 2007
22. World Health Organization. Ecosystems and human well-being: health synthesis. Available at: www.who.int/globalchange/ecosystems/ecosystems05/en/index.html. Accessed April 18, 2007
23. Etzel RA, Balk SJ, eds. *Pediatric Environmental Health*. 2nd ed. Elk Grove Village, IL: American Academy of Pediatrics; 2003
24. McMichael A, Githeko A. Human health. In: McCarthy JT, Canziani OF, Leary NA, Dokken DJ, White KS, eds. *Climate Change 2001: Impacts, Adaptations, and Vulnerability*. Geneva, Switzerland: Intergovernmental Panel on Climate Change; 2001:453–485. Available at: www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARchap9.pdf. Accessed April 18, 2007
25. Carter TR, La Rovere EL. Developing and applying scenarios. In: McCarthy JT, Canziani OF, Leary NA, Dokken DJ, White KS, eds. *Climate Change 2001: Impacts, Adaptations, and Vulnerability*. Geneva, Switzerland: Intergovernmental Panel on Climate Change; 2001:147–190. Available at: www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARchap3.pdf. Accessed April 18, 2007
26. Webster PJ, Holland GJ, Curry JA, Chang JR. Changes in tropical cyclone number, duration and intensity in a warming environment. *Science.* 2005;309:1844–1846
27. Greenough G, McGeehin M, Bernard SM, Trtanj J, Riad J, Engelberg D. The potential impacts of climate variability and change on health impacts of extreme weather events in the United States. *Environ Health Perspect.* 2001;109(suppl 2):191–198
28. Penrose A, Takaki M. Children's rights in emergencies and disasters. *Lancet.* 2006;367:698–699
29. Ahern M, Kovats RS, Wilkinson P, Few R, Matthies F. Global health impacts of floods: epidemiologic evidence. *Epidemiol Rev.* 2005;27:36–46
30. Shaw JA, Applegate B, Schorr C. Twenty-one-month follow-up of school-age children exposed to Hurricane Andrew. *J Am Acad Child Adolesc Psychiatry.* 1996;35:359–364
31. Hoven CW, Duarte CS, Mandell DJ. Mental health after disasters: the impact of the World Trade Center attack. *Curr Psychiatry Rep.* 2003;5:101–107
32. Kostelny K, Wessells M. Psychological aid to children after the 26 Dec tsunami. *Lancet.* 2005;366:2066–2067
33. Wolmer L, Laor N, Dedeoglu S, Siev J, Yazgan Y. Teacher-mediated intervention after disaster: a controlled three-year follow-up of children's functioning. *J Child Psychol Psychiatry.* 2005;46:1161–1168
34. Goenjian AK, Walling D, Steinberg AM, Karayan I, Najarian LM, Pynoose R. A prospective study of posttraumatic stress and depressive reactions among treated and untreated adolescents 5 years after a catastrophic disaster. *Am J Psychiatry.* 2005;162:2302–2308
35. Johnston C, Redlener I, eds. Hurricane Katrina, children, and pediatric heroes: hands-on stories by and of our colleagues helping families during the most costly natural disaster in US history. *Pediatrics.* 2006;117(suppl 2):S355–S460. Theme issue
36. World Health Organization. *Water, Sanitation, and Hygiene Links to Health*. Geneva, Switzerland: World Health Organization; 2004. Available at: www.who.int/water_sanitation_health/publications/facts2004/en/index.html. Accessed April 18, 2007
37. Rose JB, Epstein PR, Lipp EK, Sherman BH, Sernard SM, Patz JA. Climate variability and change in the United States: potential impacts on water- and foodborne diseases caused by microbiologic agents. *Environ Health Perspect.* 2001;109(suppl 2):211–220
38. Checkley W, Epstein LD, Gilman RH, et al. Effect of El Nino and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *Lancet.* 2000;355:442–450
39. Curriero FC, Patz JA, Rose JB, Lele S. The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948–1994. *Am J Public Health.* 2001;91:1194–1199
40. Kovats RS, Edwards SJ, Hajat S, Armstrong BG, Ebi KL, Menne B. The effect of temperature on food poisoning: a time-series analysis of salmonellosis in ten European countries. *Epidemiol Infect.* 2004;132:443–453
41. Fleury M, Charron DF, Holt JD, Allen OB, Maarouf AR. A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. *Int J Biometeorol.* 2006;50:385–391
42. Epstein PR. Is global warming harmful to health? *Sci Am.* 2000;283(2):50–57
43. Sutherst RW. Global change and human vulnerability to vector-borne diseases. *Clin Microbiol Rev.* 2004;17:136–173
44. World Health Organization. World malaria report 2005. Available at: www.rbm.who.int/wmr2005/index.html. Accessed April 18, 2007
45. Snow RW, Craig M, Deichmann U, Marsh K. Estimating mortality, morbidity and disability due to malaria among Africa's non-pregnant population. *Bull World Health Organ.* 1999;77:624–640
46. Epstein RP, Mills E, eds. *Climate Change Futures: Health, Ecological and Economic Dimensions*. Boston, MA: Center of Health and the Global Environment, Harvard Medical School; 2005. Available at: www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf. Accessed April 18, 2007
47. Centers for Disease Control and Prevention. West Nile virus: statistics, surveillance, and control. Available at: www.cdc.gov/ncidod/dvbid/westnile/surv&control.htm. Accessed April 18, 2007
48. Centers for Disease Control and Prevention. Lyme disease: United States, 2001–2002. *MMWR Morb Mortal Wkly Rep.* 2004;53:365–369
49. Lindgren E, Tälleklin L, Polfeldt T. Impact of climatic change on the northern latitude limit and population density of the disease-transmitting European tick *Ixodes ricinus*. *Environ Health Perspect.* 2000;108:119–123
50. Centers for Disease Control and Prevention. El Niño special report: could El Nino cause an outbreak of hantavirus disease in the southwestern United States? Available at: www.cdc.gov/ncidod/diseases/hanta/hps/noframes/elnino.htm. Accessed April 18, 2007
51. Centers for Disease Control and Prevention. Hanta pulmonary syndrome cases by state of residence, United States: March 26, 2007. Available at: www.cdc.gov/ncidod/diseases/hanta/hps/noframes/casemappdf.pdf. Accessed April 18, 2007
52. Centers for Disease Control and Prevention. Seal up! Trap up!

Clean up! Available at: www.cdc.gov/ncidod/diseases/hanta/hps_stc/stc_spot.htm. Accessed April 18, 2007
53. Wilson AM, Salloway JC, Wake CP, Kelly T. Air pollution and the demand for hospital services: a review. *Environ Int.* 2004;30:1109–1118
54. United Nations Population Division. World population prospects: the 2006 Revision Population Database. Available at: http://esa.un.org/unpp. Accessed April 18, 2007
55. Kim JJ. American Academy of Pediatrics, Committee on Environmental Health. Ambient air pollution: health hazards to children. *Pediatrics.* 2004;114:1699–1707
56. Knowlton K, Rosenthal JE, Hogrefe C, et al. Assessing ozone-related health impacts under a climate change. *Environ Health Perspect.* 2004;112:1557–1563
57. McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study [published correction appears in *Lancet*. 2002;359:896]. *Lancet.* 2002;359:386–391
58. Gauderman WJ, Gilliland GF, Vora H, et al. Association between air pollution and lung function growth in southern California children: results from a second cohort. *Am J Respir Crit Care Med.* 2002;166:76–84
59. Beggs PJ. Impacts of climate change on aeroallergens: past and future. *Clin Exp Allergy.* 2004;34:1507–1513
60. Ziska LH, Gebhard DE, Frenz DA, Faulkner S, Singer BD, Straka JG. Cities as harbingers of climate change: common ragweed, urbanization, and public health. *J Allergy Clin Immunol.* 2003;111:290–295
61. Beggs PJ, Bambrick HJ. Is the global rise of asthma an early impact of anthropogenic climate change? *Environ Health Perspect.* 2005;113:915–919
62. Centers for Disease Control and Prevention. Hypothermia related deaths: Alaska, October 1998–April 1999, and trends in the United States, 1979–1999. *MMWR Morb Mortal Wkly Rep*. 2000;49(1):11–14. Available at: www.cdc.gov/mmwr/preview/mmwrhtml/mm4901a3.htm. Accessed April 18, 2007
63. Basu R, Samet JM. Relationship between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiol Rev.* 2002;24:190–202
64. Bouchama A. The 2003 European heat wave. *Intensive Care Med.* 2004;30:1–3
65. National Climatic Data Center. Climate of 2006: in historical perspective. Available at: www.ncdc.noaa.gov/oa/climate/research/2006/ann/ann06.html. Accessed April 18, 2007
66. Kovats RS, Hajat S, Wilkinson P. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. *Occup Environ Med.* 2004;61:893–898
67. Wyndham CH, Fellingham SA. Climate and disease. *S Afr Med J.* 1978;53:1051–1061
68. Anonymous. Heat-related deaths: four states, July–August 2001, and United States, 1979–1999. *MMWR Morb Mortal Wkly Rep*. 2002;51:567–570. Available at: www.cdc.gov/mmwr/preview/mmwrhtml/mm5126a2.htm. Accessed April 18, 2007
69. American Academy of Pediatrics, Committee on Sports Medicine and Fitness. Climatic heat stress and the exercising child and adolescent. *Pediatrics.* 2000;106:158–159
70. American Academy of Pediatrics, Committee on Environmental Health. Ultraviolet light: a hazard to children. *Pediatrics.* 1999;104:328–333
71. Davis RE, Knappenberger PC, Michaels PJ, Novicoff WM. Changing heat-related mortality in the United States. *Environ Health Perspect.* 2003;111:1712–1718
72. Longstreth J. Public health consequences of global climate change in the United States: some regions may suffer disproportionately. *Environ Health Perspect.* 1999;107(suppl 1):169–179
73. Dessai S. Heat stress and mortality in Lisbon part II: an assessment of the potential impacts of climate change. *Int J Biometeorol.* 2003;48:37–44
74. Slingo JM, Challinor AJ, Hoskins BJ, Wheeler TR. Introduction: food crops in a changing climate. *Philos Trans R Soc Lond B Biol Sci.* 2005;360:1983–1989
75. Barnett TP, Adam JC, Lettenmaier DP. Potential impacts of a warmer climate on water availability in snow-dominated regions. *Nature.* 2005;438:303–309
76. Gruen RL, Campbell EG, Blumenthal D. Public roles of US physicians: community participation, political involvement, and collective advocacy. *JAMA.* 2006;296:2467–2475
77. Rushton FE Jr. American Academy of Pediatrics, Committee on Community Health Services. The pediatrician's role in community pediatrics. *Pediatrics.* 2005;115:1092–1094
78. Brown VA, Grootjans J, Richie J, Townsend M, Verrinder G. *Sustainability and Health: Supporting Global Ecological Integrity in Public Health*. Sterling, VA: Earthscan Publications; 2005
79. American Academy of Pediatrics, Committee on Environmental Health. Global climate change and children's health. *Pediatrics.* 2007;120:1149–1152

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