GLOBAL ENVIRONMENTAL CHANGE AND CHILDREN'S HEALTH: UNDERSTANDING THE CHALLENGES AND FINDING SOLUTIONS

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UNDERSTANDING THE CHALLENGE

We live in unique times. Human beings dominate many of earth's ecosystems[1] and are the "world's greatest evolutionary force."[2] We are transforming the planet at a speed that exceeds the adaptive capacity of many natural systems and human institutions. Anthropogenic environmental change contributes to a unique complement of environmental health hazards and social challenges, many of which are likely to affect children earlier and disproportionately compared with the general population.[3] By identifying these hazards and challenges and proactively pursuing solutions at all levels of social organization, we can make changes to protect and preserve the health of children now and in the future.

Unique Times—Unique Changes

Humanity is in the steepest portion of an exponential population growth curve.[4] It took hundreds of thousands of years for humans to reach a population of one billion but only 130 years to generate the second billion. Over the next 70 years, the population tripled to 6 billion in 1999. By 2050, we will number between 8 and 13 billion.[5] Accompanying and enabling this explosive growth has been our progressive industrialization. We have developed modern agricultural technology, harnessed multiple energy sources, improved our ability to extract natural resources, and created thousands of new chemicals and technologies.[6] Urbanization has evolved in parallel. In 1950, only 30% of the world's population lived in cities. Currently, we are evenly divided between urban and rural locations, but by 2030, more than 60% of the population will live in urban areas.[7] Finally, through modern transportation and communication technology, we are increasingly a global community.[8] Information transfer is instantaneous. National economies are interdependent. People, food, goods, and services cross borders routinely. These unique and accelerating human trends are changing the physical environment.

Human beings affect natural systems on all scales, from the microscopic to the planetary, in ways never before encountered. By burning fossil fuels, we add greenhouse gases to the atmosphere and cause climate change.[9] We have transformed half of the world's land mass, control two thirds of the world's rivers, and have harvested to the limit or beyond two thirds of the world's marine fisheries.[1] Our activities have caused an increase in the rate of extinction of species, from the 65-million-year baseline of one species extinction per million species per year to approximately 1000 species extinctions per million per year.[10] Our use of antimicrobial agents and pesticides has stimulated the natural selection of pathogens that are resistant to drugs and pests resistant to chemicals.[2] These large-scale changes create health hazards that pose immediate and long-term threats to children's health.

Immediate Threats to Children's Health

Children are one of the groups in the population most likely to experience ill health caused by environmental change.[11] Because of children's rapid growth and development and their physiologic and cognitive immaturity, they often have greater exposure and greater vulnerability to biological, chemical, and physical environmental hazards compared with other age groups.[12] The World Health Organization[13] estimates that one third of the global burden of disease is caused by environmental factors and that children younger than 5 years bear more than 40% of that burden, even though they comprise only 12% of the world's population. This disproportionate vulnerability to environmental illness is becoming evident in at least four areas of global environmental change: stratospheric ozone depletion, global warming, global movement of people and food, and synthetic chemical pollution.

Stratospheric Ozone Depletion

The stratospheric ozone layer protects terrestrial life from exposure to ultraviolet radiation (UVR), which can damage DNA and critical biological systems. Anthropogenic stratospheric ozone depletion results from the migration of manmade chemicals into the upper atmosphere, where they react with sunlight and atmospheric gases to disrupt the dynamic equilibrium between ozone production and destruction,

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causing a net loss of ozone.[14] The loss of stratospheric ozone was widely recognized in 1980 and continues to increase. Ozone depletion is most dramatic in springtime at the poles when up to 70% is lost at the south pole and up to 30% is lost at the north pole. These recurrent springtime losses have become generalized, resulting in a decrease of stratospheric ozone ranging from 3% to 6% in nonpolar latitudes. As a result, a larger amount of harmful UVR reaches the earth's surface now compared with preindustrial times. If stratospheric ozone depletion continues, the rate of UVR-related skin cancers could quadruple by 2100.[15] Data from the United States show that the incidence rate of cutaneous malignant melanoma (CMM) in 15- to 19-year-olds increased 2.6% per year between 1973 and 1995, for a total increase of 85%.[16] This example illustrates that the loss of stratospheric ozone is an immediate and escalating threat to children's health.

Global Warming

In the 20th Century, the average surface temperature of the earth increased by 0.6±0.2°C. In the 21st Century, it is projected that average temperatures will increase by 1.4°C to 5.8°C.[17] Anthropogenic greenhouse gas emissions contribute significantly to the speed and magnitude of these warming trends. Predicted direct human health effects of global warming are well described and include increased heat-related deaths, increased air pollution-related illness, increased morbidity and mortality rates from extreme weather events, increased waterborne disease, and changes in the pattern of vector-borne illnesses.[9] In each of these categories, children are at increased risk.

Temperature-related excess mortality rates are the most direct consequence of global warming. Global warming is likely to result in fewer cold-related deaths, but it is not clear if this reduction will offset increased mortality rates from heat.[18] The elderly, the debilitated, urban dwellers, the poor (20% of American children), and children 0 to 4 years of age are more vulnerable to heat stress than is the general population.[11] Heat-related deaths can be prevented by increased use of air conditioners, but when the electricity to run them comes from burning fossil fuels, "turning up the air" will produce more outdoor air pollution.[19] Children are particularly vulnerable to the adverse effects of air pollutants because they breathe more air per unit of body weight, are more physically active, and spend more time outdoors than adults.[20] Elevations in pollutants such as ozone, particulate matter, and sulfur oxides are associated with increased asthma-related emergency room visits and hospitalizations in children.[21] In industrialized societies, attempts to reduce the number of heat-related deaths are likely to increase air pollution-related health hazards for children.

Global warming will not happen gradually or homogeneously.[9] Rather, some regions will have greater impact than others, and there will be an increase in sudden and extreme weather events such as storms, floods, and droughts.[11] Violent weather events cause not only acute injury and death but also psychological morbidity, which may disproportionately affect children. For example, 21 months after Hurricane Andrew, 77% of children studied who experienced the storm had moderate to severe symptoms of posttraumatic stress, compared with 30% of adults.[22] Excessive precipitation can overwhelm sewers, storm systems, and water treatment plants, leading to increased waterborne illness. In the United States over the past 45 years, 68% of waterborne illness outbreaks have been associated with precipitation above the 80th percentile.[23] Drought threatens both water availability and water quality. Infants and young children are among the most vulnerable groups to water-related illness.[3]

Finally, global warming will change the habitat characteristics for all living creatures, including those that spread disease.[24] Insects and rodents respond quickly to changes in temperature and moisture by migrating and reproducing. The prevalence of vector-borne illness is likely to increase with global warming because increases in temperature accelerate the life cycles of disease vectors, shorten incubation times of parasites within vectors, and prolong transmission seasons. Warmer temperatures will also change the range of vectors to different latitudes and altitudes.[25] For many vectors, this will mean wider distribution and more human exposure to the diseases they carry. Infants and young children are among the groups most likely to have serious morbidity or mortality. For example, of the one million deaths from malaria each year, the vast majority occur in children younger than 5 years of age.[26] In parts of Africa, the death rate from malaria in children 0 to 4 years of age is 70 times higher than the rate in people older than 15 years of age (9.4 vs 0.13 deaths per 1000 population).

Global Movement of People and Food

The spread of vector-borne and other infectious disease is further exacerbated by globalization.[27] The global movement of people and food has contributed to the emergence, reemergence, and spread of infections including HIV, multidrug-resistant tuberculosis, multidrug-resistant malaria, mad cow disease, and *Escherichia coli* O157:H7. In the United States, a dramatic example of the effect of globalization is the emergence of West Nile virus (WNV).[28] WNV arrived in New York City, presumably by airplane, during the summer of 1999. By the end of 2001, there were 149 cases of human illness and 18 deaths reported from 10 eastern states. By the end of 2002, the count had risen to 3873 human cases with 246 deaths, and the disease was reported in 41 of the 48 contiguous United States. Although WNV is rarely fatal in children, teratogenic transplacental infection has recently been documented, highlighting the vulnerability of the fetus to this and many infections.[29] The rapidity with which this imported disease has taken hold in the United States illustrates the infectious disease challenges associated with globalization.

Synthetic Chemical Pollution

Of the more than 80,000 manmade chemicals developed since World War II, up to 75% have received little or no toxicity testing.[30] Of these, approximately 15,000 are produced in amounts in excess of 10,000 pounds annually.

Approximately 2800, termed high production volume (HPV) chemicals, are produced in amounts in excess of one million pounds annually.[31] Fewer than 45% of HPV chemicals have undergone basic toxicity testing; fewer than 10% have undergone developmental toxicity testing[32]; and fewer than 1% have undergone neurodevelopmental toxicity testing.[33] The effects on children of chronic exposure to most of these chemicals and their metabolites, individually and in mixtures, are largely unknown. In the industrialized world, where children no longer have high mortality rates from infectious disease, there are worrisome upward trends in rates of birth defects such as hypospadius,[34] neurodevelopmental diseases such as autism,[35] and life-threatening diseases such as childhood cancers.[36] Although the cause of these trends is not yet known, there is speculation that they may be related to toxic chemical exposures.

Long-Term Threats to Children

From gestation through adolescence, children are uniquely vulnerable to environmental exposures during critical windows of physical and physiologic development.[37] Exposures during childhood can cause immediate illness or cause damage that results in illness much later in life. For example, between 1972 and 1994 in the United States, the incidence of localized CMM in people older than 20 years of age increased from 5.5 per 100,000 population to 16 per 100,000 in women and 20.5 per 100,000 in men.[38] Eighty percent of sun exposure occurs before age 18 years, but UVR-related cancers occur mostly in adults. When children are exposed to outdoor air pollutants, some have deficits in lung growth and decrements in pulmonary function,[39] which may contribute to greater susceptibility to cardiovascular and lung disease in adulthood. Early exposure to chemical neurotoxicants, immunotoxicants, or endocrine disruptors may contribute significantly to diseases in adulthood.[40]

Global environmental change also threatens the long-term health of today's children because of the ecosystems and societies that children will inherit when they become adults. Predictions of the future are bleak.[13] Food and water security are in question as populations continue to grow and the environment deteriorates. Large numbers of forced migrations may occur with sudden rises in sea level, severe droughts, or prolonged famines driven by global warming. The continued loss of species will deplete biological capital and the resilience of ecosystems, threaten economic capacity, and deepen poverty. Depression, violence, and armed conflict are likely to increase as conditions deteriorate. As with the effects of climate change, these scenarios will not manifest homogeneously. Most of the population growth in the next 50 years is expected to occur in developing nations, least prepared to cope with increasing environmental, health, and social challenges.[4] Ninety percent of natural disaster victims live in developing nations.[13] Children, particularly those living in urban poverty, will be especially likely to suffer disease and death under each of these dismal scenarios.[3]

Finding Solutions

Compared with children living in the developing world, children living in industrialized countries with well-established public health infrastructures are less likely to suffer from the immediate health effects related to global environmental change. It is tempting, then, to conclude that solutions lie in raising the global standard of living to the level enjoyed in countries such as the United States. Such an approach is neither feasible nor desirable.

It is not feasible because the US lifestyle runs at a huge ecological deficit.[41] For the current world population of 6.2 billion, the planet provides about 4.5 productive acres per person to produce food, water, building materials, and fiber. To sustain the average US lifestyle requires 24 acres per person. At the current world population, it would take more than five planet's worth of natural resources to support a US lifestyle for everyone. In addition, the approach is not desirable because US children are showing signs of becoming less healthy and appear to be leading a wave of similar trends in other industrialized and transitional countries. For example, the increase in prevalence and severity of asthma and atopic illness over the last 2 to 3 decades in the United States is now seen in most industrialized countries and many developing countries.[42] Childhood obesity has tripled in the United States since 1963; 15% of children between 6 and 19 years of age are obese,[43] and other countries are reporting similar trends.[44] Pediatric mental health problems including childhood depression are widespread in the United States: 20% of American children have a mental health diagnosis, half of which are debilitating; 75% of which persist into adulthood.[45] Antidepressant use is rising, particularly in adolescents.[46] These trends and others observed over the past 2 to 3 decades are increasing at rates too rapid to be driven exclusively by genetic factors. It is likely that the physical and social environments in highly industrialized societies do not support optimal health in children.

If following the US pattern is neither feasible nor desirable, where do we look for solutions? Fortunately, examples of solutions are abundant.

At the international level, stratospheric ozone depletion was addressed through mechanisms that began with The Montreal Protocol on Substances that Deplete the Ozone Layer of 1987 and were strengthened by subsequent Amendments.[47] This unique international process is driven by science, grounded in the principles of primary prevention, and involves sacrifice in the form of abandoning useful classes of chemicals because of the long-term consequences associated with their use. The United States and 183 other nations have committed to the elimination of ozone-depleting chemicals on a global scale. Integral to the process is the recognition of differential responsibility and capacity to take action between industrialized and developing nations. Although the ultimate success of the treaties will be measured over the next few decades, the production and use of many harmful chemicals has already been greatly reduced or eliminated. It is predicted that stratospheric ozone levels will be fully restored by 2050.

This global environmental success story, though still unfolding, is a model for the future.

At the national level, environmental laws and regulations enacted since 1970 have substantially improved the quality of air and water in our country.[48] In the 1990s, several federal actions specifically addressed children's environmental health issues. Among these was the Food Quality Protection Act of 1996 (FQPA), unanimously passed by Congress, which requires that pesticides be regulated to protect infants and young children from their acute and chronic adverse health effects. Environmental health issues persist, but we can address them now by using existing political and scientific tools and at the same time develop new approaches.

Corporations model solutions when they "go green" to increase profits by eliminating unnecessary waste in the form of emissions and to increase their market share by appealing to environmentally conscious consumers.[49] One leading company voluntarily took steps to reduce pesticide residues in baby foods years before FQPA was enacted.[50] The number of "clean" technologies in the market place is growing. Examples include hybrid electric cars[51] with vastly improved fuel efficiency and CO_2 dry cleaners, which eliminate toxic solvents and even recycle some greenhouse gases.[52]

American communities are responding to unsustainable environmental pressures in a variety of ways. Urban sprawl ultimately exacerbates asthma and childhood obesity by making people dependent on automobiles to move safely about the community.[53,54] Portland is one of many communities in Oregon to develop an urban growth boundary to reduce urban sprawl.[55] Chapel Hill, North Carolina, made local bus service free and has seen the number of riders increased by 42% in the first year.[56] Broad Ripple, Indiana, is bicycle- and pedestrian-friendly, with sidewalks, bike paths, and mixed use zoning.[57] Streetlights in Calgary, Alberta, were retrofitted with full cutoff fixtures to reduce light pollution, improve ground level illumination, and enhance safety. This step also halved energy use, saving $1.4 million per year in energy cost and decreasing CO_2 emissions by 300 kg/fixture per year.[58]

At the individual level, increasing numbers of people are making choices to simplify their lives and live more "lightly" on the earth.[59] Persons in 20 US cities belong to Flexcar, a car-sharing club that started in Seattle in 1999 that effectively replaces 6 privately owned vehicles per car shared.[60] Farmers' markets and community-supported agriculture associations are thriving.[61] The swordfish population is back to 94% of sustainable levels after the international response compelled by individuals and environmental groups to "Give Swordfish a Break."[62]

All actions working toward sustainable development are ultimately public health actions. There is no "silver bullet," no single solution that will eliminate health hazards to children resulting from global environmental change. Rather, what is needed is a suite of solutions applied at all levels of society. These solutions will share some common elements: commitment to sustainability; political will to make changes, sacrifices, and to distribute the burden of change equitably; innovations in science and technology; and, above all, mechanisms to "globalize" the solutions so that all children benefit.

Pediatricians and other child health professionals should be leaders in identifying and applying sustainable solutions to environmental health problems. We have a special obligation to assume this leadership because of our tradition of advocacy and our training in preventive medicine. In our professional lives, we can incorporate environmental topics into our anticipatory guidance and clinical teaching and be meticulous at including environmental causes in our disease differential diagnoses.[12] We can teach ourselves, our patients, and our communities about environmental health hazards to children and ways to reduce or eliminate them. We can advocate for children's environmental health in our communities by supporting programs such as integrated pest management in schools,[63] shaded play areas in parks, safe corridors for bicycle and pedestrian use, and smart growth.[53] In our homes and offices, we can be role models by making choices that reduce our consumption of natural resources to sustainable levels and improve health.[59] We can walk or bike to work, post environmental health educational materials in our offices, and eliminate pesticide use in our yards. Finally, we can become deeply engaged in our political lives. We can serve on zoning commissions, advocate for smart growth in our own communities, join local and national advisory boards, provide expert testimony, interface with the media, and support individuals, laws, and policies that protect children from environmental hazards and promote sustainable development.

We live in unique times marked by unique challenges. Our curious, inventive, energetic, and very powerful species has caused many of the problems facing our children and our children's children. We know what some of the solutions are and can find others. It is time to heed these words from the international community: "For all those concerned about the environmental health of children, the time to translate knowledge into action is now."[64] It is time to get to work.

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Selected Advocacy Organizations: Physicians for Social Responsibility (www.psr.org), Environmental Defense (www.environmentaldefense.org), Children's Environmental Health Network (www.cehn.org), National Resources Defense Council (www.nrdc.org).

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