INSIDE THE GREENHOUSE

THE IMPACTS OF CO$_2$ AND CLIMATE CHANGE ON PUBLIC HEALTH IN THE INNER CITY

Paul R. Epstein and Christine Rogers

Report from the Center for Health and the Global Environment
Harvard Medical School
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The greenhouse ragweed experiments with ragweed were initiated by Susannah Foster, working with Fakhri Bazzaz, Ph.D., Mallinckrodt Professor of Biology, Department of Organismic & Evolutionary Biology, Harvard University. This report also includes a contribution on heatwaves by Laurence S. Kalkstein, Ph.D., Center for Climatic Research, University of Delaware.
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EXECUTIVE SUMMARY

Rising levels of carbon dioxide (CO₂), in addition to trapping more heat, promote plant pollen production, soil bacteria and fungi, and alter species composition by favoring opportunistic weeds (like ragweed and poison ivy). Other emissions from burning fossil fuels in cars, trucks and buses form photochemical smog that causes and exacerbates asthma, while diesel particulates help deliver pollen and molds deep into lung sacs. The combination of air pollutants, aeroallergens, heatwaves and unhealthy air masses, increasingly associated with a changing climate, causes damage to the respiratory systems, particularly for growing children, and these impacts disproportionately affect poor and minority groups in the inner cities.

The estimated cost in the U.S. of treating asthma in those younger than 18 years of age is $3.2 billion per year.

The health impacts of a changing climate include asthma and other respiratory illnesses, infectious diseases, heat stress, and preventative heart disease. Meanwhile the preventative strategies include measures that could simultaneously improve air quality and enhance the livability of urban communities.

Combustion of fossil fuels (oil, coal and natural gas) is responsible for air pollution and climate change, and air quality is a particular problem for urban centers worldwide. Traffic patterns and automotive exhaust, power plants, airports and industrial emissions are the primary sources, while wind patterns can bring in pollution and unhealthy air masses originating in other regions. Allergens (molds and pollen) originating in rural areas can reach high levels in highly populated cities.

The impacts of air pollution can be compounded by extreme weather events, whose intensity and frequency is increasing as climate changes. These events include more heatwaves, drought-driven fires, and floods. The impacts of warming are exacerbated by “the heat island effect” generated in cement cities with inadequate green space.

Today, atmospheric concentrations of CO₂ are 379 parts per million. The earth has not experienced levels of CO₂ above 280 ppm for at least 420,000 years. This report examines the direct impacts of CO₂, as well as climate change, focusing on urban centers; examining synergies between air pollution and climate change and connections between climate change and emerging infectious diseases – in particular, West Nile virus, a disease carried by urban-dwelling mosquitoes that presents new problems for public health and mosquito control authorities.
Key Points

1. **Ragweed** (in vacant lots and other disturbed areas) pollen and tree pollens (e.g., maples, birches, poplars) are stimulated by increased carbon dioxide (CO₂), and by warmer winters and early arrival of spring.

2. **Molds** are also stimulated by higher levels of CO₂. In addition, humidity, heavy rain and floods associated with climate change foster fungal growth in houses.

3. **Diesel** particles combine with aeroallergens (pollen and mold) to deliver them to immune cells in the lungs.

4. Fungal growth inside houses can affect respiratory health and insurance coverage.

5. Floods can drive rodents from their natural burrows into developed areas.

6. **Photochemical smog** (ground-level ozone) is a product of reactions between tailpipe emissions (oxides of nitrogen (NOₓ) and volatile organic compounds (VOCs)) and the chemical reaction is accelerated during heatwaves, which are intensified with climate change.

7. **Heatwaves**, unhealthy air masses, high heat indices (a function of temperature and humidity), plus lack of nighttime relief all affect cardio-respiratory illness and mortality.

8. Increased **humidity** and **nighttime temperatures** (daily minimums) are associated with a changing climate.

9. The **Heat Island Effect** can raise ambient temperatures in urban centers as much as 7°F over those in rural areas.

10. **Particulates**, carbon monoxide (CO), ground-level ozone and carcinogenic polycyclic aromatic hydrocarbons (PAHs) from drought-driven wildfires can affect populations living far from the fires.

11. **West Nile virus** in the U.S. is a new phenomenon -- a mosquito-borne disease in urban areas; one not previously faced by public health and mosquito control agencies.

12. The avian-mosquito cycle of **West Nile virus** (WNV) is amplified by warm winters, spring droughts and summer heatwaves. Bird-biting, urban-dwelling mosquitoes (*Culex pipiens*) breed in shallow pools in city drains with organically-rich litter (e.g., leaves and pollen). The disease threatens humans, birds and other wildlife.

13. **Severe and erratic weather** – early and late snowstorms, ice storms and dense fog – present hazards for automotive drivers and pedestrians.

14. **Severe storms** in coastal cities (intensified by sea level rise) can damage infrastructure, such as water and sanitation systems, with wide-ranging implications for public health.

15. **Early warning systems** of conditions conducive to large outbreaks of WNV can facilitate environmentally-friendly public health interventions.

16. Roof gardens, urban parks, tree-lined streets, “smart growth,” and improved pedestrian, bicycle and public transport can reduce the “**Heat Island Effect**.”

17. Developing **alternatives to fossil fuels** is fundamental for the protection of public health.
From extraction to combustion, oil takes an enormous toll on the environment and on public health, and the impacts fall disproportionately on poor nations and poor and minority populations within developed nations.

Exploration for oil, via road construction and penetration into unexplored forested areas (e.g., in Ecuador), has introduced infectious diseases into isolated, indigenous populations. Exploration and extraction, via oil leaks and spills into river deltas (Nigeria) and permafrost (in Alaska), contaminate fisheries, water supplies and disrupt wildlife. ‘Muds’ from off-shore drilling sites (e.g., in the Gulf of Mexico) contain mercury (a neurotoxin) that contaminates fish and harms the humans that consume them. Poor populations are especially vulnerable due to the exposures and inadequate access to health care.

Oil refineries are most often located near African-American and Native American populations in the U.S. The cancer-causing chemicals (e.g., benzene) released, primarily affect those living in close proximity to the facilities.

Coal-fired plants emit mercury that enters ground water, waterways and fish.

Combustion generates a wide spectrum of environmental and public health ills – acid rain, air pollution and climate change. Inner city populations suffer most from concentrated air pollution -- soot and ozone – and asthma rates are especially high along inner-city truck and bus routes. The combined impacts of air pollution, aeroallergens and climate change affect growing children, and these health impacts disproportionately affect poor and minority groups.

Heat waves take a disproportionate toll on those living in poor housing lacking air conditioning, and those with adequate social supports. The majority of those affected during the 1995 heat wave in Chicago, for example, were African-Americans living in substandard housing.

Extreme weather events (such as the 1998 Hurricane Mitch in Honduras, killing over 10,000; severe storms and flooding in 1999 in Venezuela, killing 20,000 and leaving 150,000 homeless; and extensive floods in 2000 in Mozambique) take their greatest toll on poor nations with inadequate resources for recovery (IPCC, 2001).

Poor nations are especially vulnerable to disasters, lacking adequate resources for coping, adaptation, rebuilding and prevention.

FULL report on the Life Cycle Impacts of Oil available on:
http://www.med.harvard.edu/chge/oil.html
The Health Impacts of Fossil Fuels

- Burning Fossil Fuels
  - Air Pollution
    - Asthma Attacks
    - Other Respiratory Illnesses
      - Premature Death from Lung and Heart Diseases
  - Greenhouse Gas Emissions
    - Climate Change
      - Heat-Related Deaths
      - Infectious Diseases
      - Injuries from Extreme Weather Events
      - Allergies
CARBON DIOXIDE, CLIMATE CHANGE AND AEROALLERGENS

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CO₂, Climate and Pollen

The Problem: Allergic diseases are the sixth leading cause of chronic illness in the US, affecting roughly 17% of the population, and costing the health care system about $18 billion annually\(^1\). Approximately 40 million Americans suffer from allergic rhinitis (hay fever), largely in response to common aeroallergens, resulting in 3.8 million lost days of work and school. Asthma is a more complex and serious disease characterized by lung inflammation resulting in shortness of breath, or wheezing. It commonly begins in childhood, and frequently requires doctor visits, medications, emergency visits, or hospitalizations. Currently, the CDC estimates that the prevalence of asthma in the US adult population is approximately 7.5% (16 million)\(^2\). The self-reported prevalence of asthma increased 75% from 1980-1994 in both adults and children. However the largest increase of 160% occurred for preschool aged children\(^3\). Low income families and African Americans are disproportionately affected by increases in prevalence, morbidity and mortality\(^2\).

Causes: Although allergic diseases have a strong genetic component, such a rapid increase in disease occurrence is likely the result of changes in environmental exposures. The factors affecting the onset of allergic diseases are complex, and considerable attention has focused on the indoor environment\(^4\), as well as outdoor particle exposures\(^5\). Diesel exhaust particles in particular have been shown to act synergistically with allergen exposure to enhance the severity of clinical symptoms\(^6\) and some suggest they may be the causal link for the increase in allergic diseases worldwide\(^7\). While the role of allergen exposure in causing allergic diseases is unknown, allergens from pollen grains and fungal spores are unequivocally associated with exacerbation of existing disease and may also play a role in other diseases such as cardiovascular disease, chronic obstructive pulmonary disease and pneumonia\(^8\). Hence, the combined effect of air pollution and outdoor allergen exposure may result in an enhanced allergic response\(^9\). Projected changes in climate over the next century will impact plant and fungal reproductive responses, and hence impact the timing, production, and distribution of aeroallergens and resulting exposures. This case study summarizes known and potential changes in pollen and fungal spore exposure, as a result of global climate change.

Climate sensitivity: Several studies have elucidated the potential impacts of global warming on plants. In general, as a result of increasing temperature and CO₂, plants will respond with enhanced photosynthesis, biomass, water use efficiency, and reproductive effort\(^10\). These are considered positive responses for agriculture, but for allergic individuals it could mean increased exposure to pollen allergens.

There are several potential climate change impacts on the timing and abundance of
airborne pollen. First, climate warming has resulted in phenological changes in plants, as in other biological systems, such that budburst in spring has advanced in recent decades \(^{11,12}\), hence the allergenic pollen season for spring flowering taxa also begins earlier \(^{13,14,15}\). The rate of these advances (0.84 -0.9 days/year)\(^{16,17}\) provide some of the best evidence of the current impacts of recent climate change. While this is generally considered to be solely the effect of temperature, some studies suggest that CO\(_2\) can independently affect phenological stages \(^{18}\).

Second, recent studies have shown increased pollen production under conditions of elevated CO\(_2\). Ragweed (\textit{Ambrosia artemisiifolia}) is a weed of open disturbed ground that produces potent pollen allergens. In controlled environment experiments, plants grown at 2x ambient CO\(_2\) had greater biomass, and produced 40 to 61% more pollen \(^{19,20}\). This was validated in field experiments using a natural urban-rural CO\(_2\) gradient but also showed that allergen content was higher in rural (low CO\(_2\)) sites \(^{21}\). Temperature and CO\(_2\) can also have interactive effects on pollen production. In experiments simulating early spring release from dormancy, ragweed plants grew larger, had more inflorescences and produced more pollen than later cohorts. Early cohorts under high CO\(_2\) produced the same amount of pollen as under ambient CO\(_2\), but later cohorts at high CO\(_2\) differed by producing almost 60% more pollen than their ambient CO\(_2\) counterparts (Rogers 2004 in prep). Long-term records at pollen monitoring stations in Europe show increasing annual totals for some types such as hazel, birch and grass \(^{14,22}\). Understanding the temporal and spatial effects of climate change is critical for projections. Increased pollen production and release in plants are modulated by weather conditions during the pollen season. Since pollen is washed out of the atmosphere by rain, increased rainfall in spring in particular regions could function to decrease overall airborne concentrations even if pollen productivity increases.

Lastly, a likely result of climate change will be shifts in the distributions of taxa as some species are able to take advantage of new conditions while others are not \(^{23}\). Droughts may create open habitat that ragweed can colonize, and therefore expand the range of this highly allergenic invasive species in Europe. Individuals may therefore be exposed to new allergens in their environment. Increased climate variability may amplify mast reproductive cycling in trees, which results in huge fluxes of allergenic pollen into the atmosphere from year-to-year.

\textbf{CO\(_2\), Climate and molds}

Evidence for climate change effects on fungal growth and reproduction is less well documented, although the implications for allergic disease are just as important. As it is for pollen, exposure to fungal spores (mold) is unequivocally associated with exacerbations of allergy and asthma \(^{4}\). Long-term field experiments with elevated CO\(_2\) show that some fungi in arbuscular micorrhizal associations with trees have enhanced growth and sporulation \(^{24,25,26}\). While more evidence is needed to establish the certainty of these effects for a wider range of fungi, plausible arguments can be made for the likelihood of increased fungal biomass which would be needed to degrade the increased plant biomass projected under climate change scenarios.

Fungi are also an important factor in indoor environment exposures leading to allergic and asthmatic events. Increased, and more widespread, reliance on air conditioning will become common, and mismanagement of building ventilation and may lead to inappropriate moisture conditions in buildings. Changes in precipitation regimes are anticipated, with heavier downpours and more widespread flooding. Increased flooding in coastal areas is also projected with increases in sea level. All of these scenarios indicate a higher likelihood of wet interior surfaces that are prone to fungal growth. Several studies have shown that home dampness is a
significant predictor of respiratory symptoms\textsuperscript{27,28}. Inequities are likely to occur as lower income families are less able to cope with expensive remediation or flood insurance (if available). Because of mold litigation and high jury awards, many home insurance policies currently have exclusions for mold growth.

For developing nations and poor communities, the health impacts may be significant. As developing countries incorporate modern technologies to cope with climate change (e.g. air conditioning, indoor plumbing) on a wider scale, the resulting problems associated with poor building construction and maintenance also increase unless there is an influx of technological and financial resources.

**Summary of key issues**

Increasing asthma prevalence worldwide signals an expansion of the vulnerable population. Climate change (with both increased temperature and CO\textsubscript{2}) will likely result in increased production of pollen (and possibly fungal spores). Spring pollen allergy seasons are occurring earlier and shifts in plant ranges will expose individuals to new allergens. Flooding and hurricanes increase potential exposure to airborne fungal spores indoors particularly in populations ill-equipped to handle remediation. Air pollution will act synergistically with the allergens to further deteriorate respiratory health.

**Economic Implications**

Beyond health care costs – clinic, ER visits, hospitalizations, and medications – are school absences, work absences (adults as patients and parents) and lost productivity. The same issues can contribute to Chronic Obstructive Pulmonary Disease, susceptibility to Influenza and increased mortality.

**REFERENCES**


OVERVIEW OF CLIMATE CHANGE AND URBAN PUBLIC HEALTH

Introduction

The U.S. National Assessment of the Impacts of Climate Change and Variability (www.usgcrp.gov/usgcrp/nacc/default.htm) projects that there will be changes in the climate and in weather patterns in every region of the United States in coming decades as a result of increasing atmospheric concentrations of greenhouse gases. These predictions are in keeping with those of the U.N. Intergovernmental Panel on Climate Change for the planet as a whole (Houghton et al., [IPCC] 2001). Changes will involve warming temperatures -- with the largest increases occurring at higher altitudes and latitudes, and during the winter and at night. The warming is also associated with an increase in extreme weather events, with heavy rains (>2”/day) and flooding in some areas and prolonged drought in others.

Accompanying the warming and anomalous weather, major impacts on urban infrastructure are projected, as well as impacts on terrestrial and marine ecosystems; affecting wildlife, forests, agriculture and human health. This brief summary will outline the potential health impacts of climate change and variability and will discuss in more detail three case studies in the U.S. that provide useful models for understanding the relationship of human health to climate and weather.

The following categories of diseases and other health impacts may be affected by climatic conditions and weather. While each one (e.g., heatwaves or emerging infectious diseases) can occur in the absence of climate change, it is projected that climate change and the associated alterations in weather patterns will influence the frequency, intensity and geographic distribution of these health outcomes. Understanding the health/climate/weather connections can:

a) Help generate early warning systems for environmentally-friendly public health interventions; and
b) Help monitor and understand the short and long-term health consequences of climate change and the associated changes in weather patterns.

Areas Covered

- Heat stroke, dehydration, heat exhaustion and heat waves
- Cardio-respiratory disease and air quality
- Emerging infectious diseases (EIDs) and climate warming and variability
- Traumatic injuries and extreme weather
- Gastro-intestinal infections and water quality

Additional issues include: morbidity and mortality associated with weather-related impacts on food quality, especially seafood, and the health impacts of sea level rise and storm surges (e.g., from flooding, salt water intrusion of well water, etc.).
Heatwaves

Recent record-high temperatures in many parts of the United States and Europe highlight the need for an awareness of the health hazards posed by global warming. Heatwaves can cause dramatic increases in overall morbidity and mortality, and they have increased the number of deaths per day 2 to 3-fold over baseline levels in particularly severe episodes (http://www.cdc.gov/mmwr/preview/mmwrhtml/0000041.htm).

From 1979–1999, excessive heat exposure caused 8,015 deaths in the United States. During this period, more people in this country died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined (http://www.cdc.gov/nceh/hsb/extremeheat/).

The incidence of heat waves in most U.S. cities is expected to approximately double by the year 2050 by current climate change estimates (Kalkstein, 2000).

The health impacts of heatwaves are a function of average temperatures, nighttime temperatures (minimum), and the heat index (which is a measure of humidity and temperature combined, where high humidity levels interfere with the human body’s ability to cool itself by transferring heat, through radiation and evaporation, to its surroundings). Minimum nighttime temperatures have been rising twice as fast as overall warming since 1950 (Karl et al., 1993; Easterling et al., 1997), which is predicted by climate change models. The “heat island effect,” where the heat generated by cement streets, buildings and the cumulative activities of populations increases the ambient temperature 5–10°F above that of surrounding, less urbanized areas, is present in most U.S. urban centers and adds to the intensity of heatwaves. It is, in turn, affected by the presence of urban trees and parks, roof gardens, and heat reflective building colors, particularly on rooftops.

Case Study: The Chicago Heatwave of 1995

The Chicago heatwave in the summer of 1995 well illustrates how heat waves influenced by climate change will affect human populations. In this case, there was the lethal combination of high humidity and unusually high nighttime temperatures, so that Chicago residents had little relief at night (CDC, 1995; Whitman et al., 1997). During July 12-16, 1995, Chicago experienced unusually high maximum daily temperatures, ranging from 93°F to 104°F (33.9°C to 40.0°C). On July 13, the heat index peaked at 119 F (48.3 °C) -- a record high for the city.

During July 11-27 the Cook County Medical Examiner's Office (CCMEO) certified 465 as heat-related, compared with no heat-related deaths during the period of July 4-10. The highest number of heat-related deaths previously certified by the CCMEO was 77 in association with a heat wave in the summer of 1988. During July 13-21 (the period with the most heat-related deaths), a total of 1177 deaths occurred in Chicago -- an 85% increase over the same period in 1994 (637 deaths). A subsequent analysis demonstrated that there were at least 700 excess deaths in Chicago
during the heat wave, most of which were heat-related (Semenza et al., 1996). And recent reports have confirmed that there were long-term neurological effects among some of those who had heat stroke but survived (reference to be obtained).

Those at greatest risk of dying from the heat wave were people with chronic medical illnesses. But socioeconomic factors were involved as well; poor and socially isolated people without access to air conditioning were disproportionately affected. Early warning systems are now in place in some U.S. cities (Kalkstein, 2000) and Canada (Smoyer-Tomic et al., 2001), with a program to identify those who live alone, particularly those who are chronically ill medically or psychiatrically. Effective measures for preventing heat-related illness and death include reducing physical activity, drinking nonalcoholic liquids, and spending time in air-conditioned environments.

Severe summer heatwaves, with numerous attributable deaths, have become increasingly common in developing nations as well, notably New Delhi, India.

Case Study: The European Heatwave of 2003:
An Analog for the United States

Laurence S. Kalkstein, Center for Climatic Research, University of Delaware

Heatwaves in the northern hemisphere can be defined as three consecutive days with temperatures greater than 90°F. Prolonged events are often accompanied by droughts. Heatwaves and droughts are expected to be more intense and more common with climate change.

Disease outcomes of heatwaves include heat-related deaths, crop losses, wildfires, and high ground-level ozone (photochemical smog).

Current models project a doubling of heat-related mortality in many U.S. cities by 2020, and a tripling by 2050.

The devastating heat wave in Europe this past summer was unprecedented for many major cities on the continent. As a result, an estimated 35,000 people died from the direct results of heat, with most deaths concentrated in Western Europe. Although it is uncertain whether a long-term climate change was in any way responsible for this highly unusual event, it is now plausible to consider this heat wave as an analog – a possible example of what might happen more frequently if a human-induced climate change becomes more pronounced.

An even greater threat involving the European heat wave has been brought to light in a recent issue of Nature (Schar et al., 2004). The authors argue that a heat event of the magnitude of summer, 2003 in Europe is “…statistically extremely unlikely…”, and can only be explained by a regime that leads to increased summer temperature variability. From a human health standpoint, this is a very negative outcome, since many have argued that the impact of heat upon human mortality would increase most dramatically in a warmer world if climate variability also increased (Kalkstein and Greene, 1997).

Initial observations developed for the U.S. EPA indicate that a comparable heat wave in
the U.S. would be a devastating event. Transposing similar temperature deviations that occurred in Paris to Washington, DC, it is apparent that the heat wave would break all-time records (Kalkstein, unpublished). The highest temperature ever recorded in Washington is 106°F. Using the same day-to-day deviations that occurred in Paris transposed to Washington, there would have been an 11 consecutive day period in which each day would have broken this all-time record. Nine consecutive days would have recorded temperatures exceeding 110°F, and one day would have reached 116°F. (Kalkstein, unpublished).

Cardio-Respiratory Disease And Air Quality

The following are examples of how climate change may affect cardio-respiratory disease:

Pollen
Pollen release from ragweed and some tress (e.g., birches and poplars) is increased by higher levels of atmospheric CO₂ (in the case of ragweed, with a doubled CO₂ concentration, 60% more pollen is released) (Wayne et al., 2002). Warm winters and the early arrival of spring may exacerbate this effect. Increased pollen levels may explain some of the increased incidence of asthma and respiratory allergies.

Ground-level ozone or photochemical smog
The reaction of oxides of nitrogen (NOₓs) and volatile organic compounds (VOCs) (both tailpipe emissions) is temperature-dependant; i.e., heat increases smog. Ground-level ozone, which is also increased by higher levels of ultraviolet B radiation from stratospheric ozone depletion, has been shown to cause asthma in children and to trigger attacks (McConnell et al., 2002). Photochemical smog also causes increased morbidity and mortality in those with chronic obstructive pulmonary disease.

Diesel exhaust particulates
These particles (direct air pollutants from burning fossil fuels) cause significant illness, especially when they are smaller than 10 microns in diameter and can bypass the lung’s defenses.

They can: (1) Clog airways and cause acute, and worsen chronic, cardiovascular and respiratory illness; (2) Help deliver pollen grains and molds deep into the lung; (3) Help cause lung cancer.

Heatwaves
Prolonged high temperatures can result in temperature inversions, leading to trapped masses of unhealthy air contaminated by smog, particulates, and other pollutants.

Fires
The incidence of forest fires is increased by drought secondary to climate change, and to the lack of spring runoff from reduced winter snows. These fires create smoke and haze which can settle over urban populations causing acute and exacerbating chronic respiratory illness (e.g., the Heyman fire in Colorado, summer 2002). The extensive, severe forest fires in Indonesia in 1997/98 were the result of small fires, started to clear the forests for agriculture, which quickly became out of control due to a severe drought. The resulting plume of smoke settled as haze over large down-wind populations in Southeast Asia, causing widespread respiratory illness.
Emerging Infectious Diseases

Since 1976, the World Health Organization reports there are 30 infectious diseases that are new to medicine. These include Ebola, Legionellae', Lyme disease, Hantavirus Pulmonary Syndrome, a new strain of cholera (Vibrio cholerae O139), E. coli O157:H7, HIV/AIDS, and a host of antibiotic-resistant organisms. In addition, there is a resurgence of some old diseases (malaria, dengue fever, cholera), and a redistribution of others (e.g., West Nile virus) occurring on a global scale. Many emerging diseases are zoonoses, or animal diseases, that spill over to humans, and are responsive to environmental change and climatic variability. For example, “explosions” of rodent populations can follow droughts punctuated by heavy rains, because such weather patterns can result in a decreased population of rodent predators and an increased supply of food (this was the case, for example, with the outbreak of Hantavirus Pulmonary Syndrome in the four corners area of New Mexico in 1993).

Moreover, climate (especially winter minimum temperatures) can restrict the geographic range of some infectious diseases by altitude and by latitude (in the case of vector-borne infectious diseases, for example, by being too cold above a certain altitude or latitude for a vector, host, or infectious agent to survive) (Epstein et al., 1998), while weather can affect the timing, intensity, and location of outbreaks. Rising minimum winter temperatures are particularly important in allowing the over-wintering of some diseases vectors (e.g., ticks or mosquitoes), and in increasing the number of reproductive generations (e.g., rodents). In addition, extreme weather events (especially droughts and floods) often precipitate clusters of rodent-, mosquito- and water-borne diseases (Epstein, 1999).

Case Study: West Nile Virus

West Nile virus (WNV), first reported in Uganda in 1937, is a zoonosis (a disease involving an animal), with “spill-over” to humans. WNV also poses significant risks for wildlife, zoo and domestic animal populations. While it is not known how West Nile virus (WNV) entered the New World in 1999, anomalous weather conditions appear to have amplified this Flavivirus, which circulates among urban mosquitoes, birds and mammals. Analysis of weather patterns coincident with a series of U.S. urban outbreaks of St. Louis encephalitis (SLE) -- a disease with a similar life cycle that first occurred in the U.S. in 1933, coincident with the ‘Dust Bowl’ era -- and four recent large outbreaks of WNV, reveal that drought was a common feature. Culex pipiens, the primary mosquito vector (carrier) for WNV, thrives in city storm drains and catch basins, especially in the organically rich water that forms during drought, The accompanying warm temperatures also accelerate the period of maturation of viruses (and parasites) within mosquito carriers, enhancing the potential for transmission. As the potential risks from pesticides for disease control must be weighed against the health risks of the disease, an early warning system of conditions conducive to amplification of the enzootic cycle could help initiate timely preventive measures, and potentially limit chemical interventions.
Significant outbreaks of WNV in the past decade

Romania 1996: A significant outbreak of WNV occurred in 1996 in Romania, in the Danube Valley and in Bucharest. This episode, with hundreds experiencing neurological disease and 17 fatalities, coincided with a prolonged drought and a heatwave.

Russia 1999: A large outbreak of WNV occurred in Russia in the summer of 1999, following a warm winter, spring drought and summer heatwave (Platanov et al., 2004).

Israel 2000: WNV was first reported in Israel in 1951, a major stopover for migrating birds. In 2000 the region was especially dry, as drought conditions prevailed across southern Europe and the Middle East, from Spain to Afghanistan.

US 1999: In the spring and summer of 1999, a severe drought (following a mild winter), affected Northeast and Mid-Atlantic States, and a three-week July heat wave enveloped the Northeast. In the N.Y. area seven people died, and, of the 62 people who suffered neurological symptoms and survived, the majority reported chronic disabilities.

US 2002: In the summer of 2002 much of the West and Midwest experienced severe spring and summer drought. Lack of snowpack in the Rockies (warmer winters are characteristic of climate change) contributed. An explosion of WNV cases occurred (see chart), with humans or animal infection documented in 44 states and the District of Columbia. WNV can be transmitted via organ transplants, in-utero and through blood transfusions.

Of greatest concern WNV spread to 230 species of animals, including 138 species of birds and 37 species of mosquitoes. Not all animals fall ill from WNV, but the list of hosts and reservoirs includes: dogs, cats, squirrels, bats, chipmunks, skunks, rabbits and reptiles. Raptors (owls, kestrels) have been particularly affected; West Nile virus likely caused thousands of birds of prey to die in Ohio and other states in July 2002. Some zoo animals died.

In the summer of 2003 cases clustered in Colorado and other states west of the Mississippi, where drought conditions prevailed.

Note: The population impacts on wildlife and biodiversity have been inadequately evaluated. Declines in raptors – condors, owls, hawks and eagles – could have dramatic consequences for human health, for raptors prey upon rodents, keeping their numbers in check. When rodent populations “explode” – when floods follow droughts, forests are clear-cut, or diseases attack predators – their legions can become prolific transporters of pests and pathogens, including: Lyme disease, leptospirosis, plague, hantaviruses and hemorrhagic fevers.

As of April 2004, the Centers for Disease Control and Prevention (CDC) reported for 2003:

Human cases: 9,858
Deaths: 262
Equine cases: 14,045
Death rate (before vaccination): ~1/3

There is the potential for outbreaks throughout the Americas. In April 2004 birds were reported infected in California and, in Ohio, a 79 year-old man developed the illness.
Public Health Implications

Factors other than weather and climate contribute to outbreaks of these two diseases. Antiquated urban drainage systems leave more fetid pools in which mosquitoes can breed, and stagnant rivers and streams do not adequately support healthy fish populations that consume mosquito larvae in isolated standing pools. Such environmental "vulnerabilities" present opportunities for environmentally based public health interventions following early warnings of conducive meteorological conditions.

State plans to prevent the spread and contain WNV have four components: (1) Mosquito and dead bird surveillance; (2) Community communications and media outreach; (3) Source (breeding site) reduction though larviciding with bacteria (*Bacillus sphaericus*) and Altocid (methoprine) and neighborhood clean-ups, and (4) Pesticide (pyrethrins, synthetically derived from chrysanthemums) spraying, when deemed necessary.

The information on predisposing climatic conditions and predictions of them may be most applicable for areas that have not yet experienced WNV, but lie in the flyway from Canada to the...
Gulf of Mexico. Projections of droughts (e.g., for Northeast Brazil during an El Niño event) could help focus attention on those areas, enhancing surveillance efforts (including active bird surveillance), public communication and environmentally-friendly, public health interventions. They may also help to set the stage for earlier chemical interventions once circulating virus is detected.

Finally, in terms of the public perception and concerns over the risks of chemical interventions: understanding the links of WNV to climatic factors and mobilizing public agency departments, such as water and sewage services, to address a public health threat may prove helpful in garnering public support for the combined set of activities needed to protect public health.

**West Nile virus Cases and Deaths**

<table>
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<tr>
<td>2003</td>
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</tr>
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</table>
**Traumatic Injuries And Extreme Weather Events**

Anomalous weather and extreme events have increased in intensity, and they are projected to increase in frequency, as climate changes (IPCC, 2001). Some events, like heat waves, have already become more common; droughts have become more prolonged, and heavy rain events (>2”/day) have increased over the past century (Karl et al., 1995; Easterling et al., 2000). Storms can effect populations directly, but they can also do so indirectly, as they can increase the number of breeding sites for disease vectors; and drive nutrients, microorganisms and toxic chemicals into waterways and water supplies, affecting both the food and water supply. Fog, avalanches, ice, wind and hail storms are all potentially affected by changes in ambient temperatures and alteration of the hydrological cycle.

With warming, there is both an increased evaporation of water from land and from the oceans, and an increased capacity of the atmosphere to hold water. As a result, there is increased cloud formation and when it does rain, the rains can be torrential. This has been observed in recent hurricanes in the U.S. (e.g., Hurricane Floyd, drenching the Mid-Atlantic States in September 1999), and in Hurricane Mitch in Central America in November 1998 in Honduras (with six feet or rain over 3 days). Intense precipitation events have led to flooding, mudslides, the wash out of roads and bridges, and the resulting injuries and deaths from drowning, car accidents, and the collapse of homes and other buildings. The freezing rain and ice storms seen in winter are also the result of warming temperatures, leading to driving and pedestrian hazards.

Ice storm traffic deaths and power outages, such as those occurring in the winters of 2002 and 2004 are examples of the potential impacts of anomalous weather. Freshening of the ocean in the North Atlantic – from melting ice and rain falling at high latitudes – may be altering winds and weather patterns in the Northeast of the U.S. and in Europe. If the Gulf Stream were to change course, the climate in these two regions would become like that of Siberia (NAS, 2001).

**Gastrointestinal Infections And Water Quality**

Water quality and availability are affected by climate and weather. Some parts of the U.S. are experiencing chronic shortages of precipitation (e.g., the West and Midwest), while others are experiencing an excess (e.g., the Northwest). [Water withdrawals and competing uses are contributing to water problems in many parts of the U.S., and changes in precipitation patterns are exacerbating the issues of shortages in some parts and excess in others.]

**Case Study: The Milwaukee Cryptosporidium Outbreak: 1993**

Floods are related to water-borne diseases. The torrential rains in 1993 (that led to the flooding of the Mississippi River valley) resulted in the largest waterborne disease outbreak in U.S. history in Milwaukee, Wisconsin. The rains washed a protozoan called *Cryptosporidium* from farm lots (it is present in the stools of livestock) into surface waters that supply
Milwaukee with drinking water. An estimated 403,000 persons contracted Cryptosporidiosis, a gastrointestinal infection of varying severity in different populations. This constituted an incidence rate of 52% among all those served by the South Milwaukee water works plant (MacKenzie et al., 1994). In most people exposed, the infection was mild and self-limited and did not cause serious illness. In others, especially in those with compromised immune systems (e.g., those with HIV/AIDS infections or those being given chemotherapy for cancer), the situation was very different. In this group, there were over 100 deaths (Vakill et al., 1996).

An extensive study of water-borne disease outbreaks for the U.S. demonstrates the strong association with heavy rain events and flooding (Curriero et al., 2001) (Also see review of climate and disease: Patz et al., 2001).

Food Quality

Food quality is affected by heat. Episodes of bacterial food contamination in Japan are highest during the summer, and notable outbreaks have accompanied prolonged summer heatwaves (McMichael et al., 1996).

Seafood contamination with biotoxins (biological toxins) is associated with “red tides,” or harmful algal blooms (HABs). Excess nutrients and the loss of filtering wetlands, combined with warm, stagnant seas can lead to red tides and outbreaks of shellfish contamination (paralytic, neurological, amnesic and diarrheic shellfish poisoning). In addition, heavy rains can flush nutrients into estuaries and coastal zones, triggering HABs (Epstein et al., 1998; Harvell et al., 1999).

Sea Level Rise And Storm Surges

Sea level rise (SLR) presents a longer-term threat to infrastructure and human health. SLR can lead to salinization of underground water, with implications for hypertension and the availability of potable water. SLR can also increase the frequency of storm surges and associated damage to infrastructure and sanitation systems, contamination of ground and surface water with farm animal wastes, and the overflow of Combined Sewer systems.
REFERENCES


CONCLUSIONS AND RECOMMENDATIONS

Rising carbon dioxide levels in themselves pose health hazards, due to their impacts on plants and soil organisms. As the primary fossil fuel-generated greenhouse gases, the rising levels are altering the earth’s heat balance. Local initiatives on individual, organizational, city, state and regional levels can go along way towards improving energy efficiency, group purchasing of energy from alternative sources feeding into the grid, upgrading fleets to hybrids, and many more such interventions with rapid “pay-back” periods.

Converting from fossil fuel use to greater energy efficiency, hybrid vehicles, alternative sources, “green buildings,” and improved public transport would reduce all the by-products of extraction and combustion (including NOxS, SOxS, VOCs, particulates and mercury), reduce CO2 levels now altering plant growth and soil organisms and help to stabilize the climate.

A properly-financed clean energy transition would produce many new industries, new jobs and boost international trade. The clean energy transition can become the engine of growth for the 21st Century, helping to alleviate poverty and initiate a more equitable, healthy and sustainable form of development.
APPENDIX

STRATEGIES TO REDUCE PUBLIC HEALTH IMPACTS OF CLIMATE CHANGE AT THE LOCAL LEVEL

This is a sector-by-sector list of measures local governments can implement to reduce greenhouse gas (GHG) emissions in their community and in their own facilities and operations. The International Council for Local Environmental Initiatives (ICLEI) (including over 500 local governments worldwide; 130 cities and counties in the U.S.) has software to assist municipalities with the task of measuring GHG emissions and developing local action plans.

Residential Sector

- Setting energy efficiency standards for new construction or major renovations
- Requiring light colored, high albedo rooftops and pavement
- Ordinance for energy efficient retrofit in existing building stock at time of sale
- Solar access ordinance
- Solar hot water/pool heating and solar PV applications, ordinance or incentives
- Passive solar design and solar orientation incentives, guidelines, ordinances
- Financial incentives e.g. tax incentives, rebates, loans, etc.:  
  - For installation of photovoltaics, other renewable energy application
  - For more efficient appliances, e.g. refrigerators, lighting, water heaters
  - For improving efficiency in existing and new buildings
- Home insulation or weatherization program
- Distribute water saving devices, such as low-flow shower heads and faucet aerators
- Distribute compact fluorescent bulbs, other home energy saving devices
- Education and promotion of "cool communities" type landscaping
- Tree planting program to maximize shading of buildings

Commercial Sector

- Raising energy efficiency standards for new construction, significant renovations, remodeling, additions, other activities requiring permit
- requiring light colored, high albedo rooftops and pavement
- Ordinance for energy efficient retrofit in existing building stock at time of sale
- Solar access ordinance
- Provide energy services to business, e.g. audits, assessments for energy efficiency improvements, other technical assistance
- Cooperative or aggregate purchase or buyer program for lighting, efficient equipment
- Distribute compact fluorescents, lighting occupancy sensors, other commercial application energy saving devices
- Lower business fees or waive permits for energy efficiency improvements and use of solar energy
- Building Energy Tax Credit
- Comprehensive municipal retrofit of existing buildings, parks, stadiums, swimming pools and other recreation facilities, e.g. lighting, insulation, HVAC systems
Building-specific renewable energy applications, e.g. installing solar hot water heating for locker rooms of recreational facilities
- Lighting efficiency improvements
- Energy efficiency standards for renovations and new construction of municipal buildings
- Lighten colors of existing rooftops and street paving to reduce “heat island” effect
- Rooftop gardens, greening of buildings surroundings for cooling
- Building-specific fuel switch from electricity to natural gas
- Implement co-generation or heat recovery
- Procurement policies that specify energy efficiency standards in all purchasing and bid specs for office equipment, motors, lighting, appliances, etc

**Industrial Sector**

- Ordinance establishing energy efficiency requirements for new industrial permits
- Ordinance requiring industries to develop and implement energy conservation programs
- Ordinance lowering business fees or waiving permits for energy efficiency improvements and fuel switching (including use of solar energy), heat recovery/co-generation systems
- Provide energy services to industry, e.g. audits, assessments to recommend process changes, other energy efficiency improvements

**Transportation Sector**

- Implement policy shifting funding away from roads and highways to alternative transit

- Increase use of alternative transit - public transit, van-, carpooling, cycling, walking through:
  - Funding for facility, system and/or infrastructure improvements
  - Dedicated lanes for transit/HOV vehicles
  - Implement free bike share program
  - Work with transit authority to reduce public transit fares
  - Ordinance providing parking fee and road toll discounts for van- and car-pools
  - Jitney or shuttle service connecting neighborhoods to commuter lines

- Establish service center selling transit passes, coordinating car/van pooling, ridesharing, etc.
- Trip Reduction Ordinance or policies requiring or promoting programs to encourage use of transit, ridesharing, telecommuting, business-sponsored parking cash-out programs
- Establish solar PV or other electric vehicle charging station
- Establish or facilitate road tolls to decrease motor vehicle use
- Parking policies:
  - Implement program to remove public parking
  - Implement program of reduced parking fees for HOVs or high-MPG vehicles
  - Zoning ordinance that reduces minimum parking space requirements for new construction
  - Parking fees to fund transit use, bicycle or pedestrian improvements
Fleet

- Downsize current and future vehicles through procurement policy changes
- Reduce fleet size, i.e., total number of vehicles
- Improve scheduling and route efficiency
- Change procurement policy to specify high fuel efficiency for each vehicle class
- Improve maintenance regime for increased efficiency, e.g., check tire pressure
- Replace on-the-job driving with telecommunications, transit, bicycling, walking, and car-pooling
- Provide incentives to reduce municipal employee travel, e.g., trip reduction policies like subsidized transit passes, elimination of free parking, preferred parking for carpools, vanpools

Land use

- Zoning or land use policy changes to promote infill development
- Zoning ordinance that promotes high-density development
- Zoning change to reduce parking requirements and allowances
- Density bonuses and incentives for high-density, infill, and transit-oriented development
- Impact, facility, mitigation, and permit fees that discourage sprawl

Water

- Energy-efficient retrofit of facilities, especially pumping processes
- Energy-efficient specs for new construction of sewage and waste water system
- Improve energy-efficiency of equipment
- Process changes to improve energy-efficiency of treatment of drinking water, wastewater and sewage
- Change energy source from electricity to natural gas for existing operations

Waste

- Increase office recycling, e.g., paper, cardboard, cans, toner cartridges
- Recover food waste in cafeterias and kitchens of local government buildings for composting or other use
- Waste prevention in day-to-day operations—two-side copying, reduced paper requirements, etc.
- Purchasing preferences for recycled materials
- Compost park, street, and other landscaping debris for re-use by Parks and Recreation
- Recover landfill methane for energy production
- Establish a center for reusing salvageable goods
- Home composting education program, compost bin distribution
- Collect curbside yard debris
- Implement or expand residential curbside recycling collection
- Improve or expand commercial recycling collection
- Community recycling drop-off sites
- Financial incentives to reduce waste such as:
  - Pay-as-you-throw or unit pricing
  - Special taxes and tipping fees
  - Advance disposal fees
- Implement landfill methane collection program
Others

- Implement or participate in district energy programs, i.e. district heating and cooling
- Implement public education programs, e.g., special events, PSAs, curricula
- Implement urban forestry projects
- Establish energy efficiency or climate protection information clearinghouse

Measures affecting Gas and Electric Utilities

- Purchase “green power” and specify renewable energy content for local government operations
- Negotiate minimum standards for renewable energy portfolio
- Negotiate aggregate purchasing contracts that specify renewable power for commercial and residential sectors
- Implement program offering residents and businesses the option of purchasing renewable power for a surcharge
- Local Government Measures

Lighting

- Replace existing lighting with energy-efficient and low-wattage lamps and ballast
- Reduce energy use through reducing hours of operation and/or number of lights
- Solar Photovoltaic (PV) powered street and emergency lighting
- Switch traffic signals, exit signs from incandescent bulbs to Light Emitting Diodes (LEDs)

Procurement

- Modify purchasing policies to specify energy efficiency standards in all purchasing and bid specs for office and heavy equipment, motors, lighting, appliances, etc.
- Purchase “green power” and specify renewable energy content for local government operations

Financing

- Establish financing program for efficiency improvements in the community, e.g., revolving loan funds through bonds, energy taxes, etc