IMPLICATIONS OF ATMOSPHERIC AND CLIMATIC CHANGE FOR HUMAN HEALTH

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Summary

Several aspects of human-induced changes in the earth's atmosphere threaten health. The stratospheric ozone layer that protects the biosphere from exposure to potentially lethal levels of ultraviolet radiation is being damaged by human-made ozone-destroying substances, particularly chlorofluorocarbons. This family of chemicals had been widely used in industry as solvents, refrigerants, and aerating agents until their harmful effects, which had been theoretically predicted, were observed and the dangerous consequences appreciated.

A more serious harmful form of atmospheric change is accumulation of increasing concentrations of greenhouse gases, notably carbon dioxide. These gases are mostly produced by combustion of fossil fuels. The rising atmospheric burden of carbon dioxide is a consequence of industrialization. Measurements of carbon dioxide concentrations in trapped air bubbles in ice cores dating back many thousands of years have shown that from the end of the last ice age until the beginning of the industrial era about 1800, atmospheric concentrations remained fairly constant. Since then they have risen sharply. The earth's average ambient temperature has risen in response, with consequences that, early in the twenty-first century, give cause for concern about long-term prospects for global sustainability.

A third physical and chemical change in the composition of the atmosphere is production of smog and associated acid precipitation, caused by combustion of fossil fuels; this is primarily a local and regional problem. It causes chronic respiratory damage with acute exacerbations during smog episodes, and if these occur during prolonged heat waves associated with global warming the combination can be lethal for

people in frail health.

These phenomena, and the policies and public health measures necessary to deal with them, are the subject of this article.

1. Introduction

In 1896, the Danish astronomer Svante Arrhenius pointed out that the earth's gaseous halo of nitrogen, oxygen, and small amounts of other gases including carbon dioxide (CO_2) protected the biologically sensitive regions at the earth's surface where earth, sea, and sky meet, filtering solar radiation and dampening its effects on ambient temperatures. Without this insulating layer of delicate invisible gases, the earth's surface temperature would fluctuate daily from highs of 60°C or more under the midday sun to lows of 10°C or more below zero at dawn—a range so wide that few existing life forms could flourish. Moreover, the earth's surface would be exposed to levels of solar ionizing ultraviolet radiation (UVR) that would be incompatible with any form of life as we know it. Most of the dangerous UVR is filtered by the stratospheric ozone layer, which prevents it reaching the earth's surface.

We have learnt a lot about the influence of atmospheric composition on human and other forms of life on earth since 1896. Meteorology and atmospheric physics remain inexact sciences, but increasing scientific evidence and many empirical observations have led the eminent groups of scientists comprising the Intergovernmental Panel on Climate Change (IPCC) to conclude that humans, and other living creatures with which we share the earth, are at risk of harm because of changes to the atmosphere that are largely a consequence of human actions.

2. The Context of Atmospheric and Climate Change

Atmospheric and climate change are among several interconnected global changes induced by human activities that have implications for human health (see Table 1).

		Evidence	Impact
Atmosphere	Greenhouse gases rising	+++	Global
	Stratospheric ozone attenuation	+++	Global
	Air pollution (mainly urban regions)	+++	Regional
Resource depletion	Water	++	Regional
	Fuel, energy	+	Local
	Forests	+	Local
	Fisheries	++	Regional
	Agricultural land	+	Local
	Wilderness	++	Regional
Species	Extinctions	++	Global
	Reduced biodiversity	++	Regional
	Emerging pathogens	+++	Global
Demographic	Population quadrupled in twentieth century	+++	Local

	Urbanization (now near 50% urban)	+++	Local
	Migration (rural-urban, international)	+++	Local
	Aging (higher % older)	++	Local
Economic	Industrialization	+++	Local
	Globalization	+	?
	Rich/poor gaps widening	+	Global
Political	Democratization	+	Regional
	Political volatility	++	Local
	Short-term versus long-term planning	++	?
	Regional and local conflicts	+++	Local
Cultural	Communication greatly increased	+++	Global
	TV's "Global village"	+	Global
	"Dumbing down"	?	?

Table 1. Human-induced global changes with health impacts
(*Source*: J.M. Last, *Public Health and Human Ecology* (Stamford, CT: Appleton & Lange, 1997))

Resources, notably fresh water for drinking and irrigation, and some food sources are being depleted. Tropical and boreal rain forests are being "harvested" for timber and newsprint at unsustainable rates. Clear-cutting on steep hillsides has caused serious erosion of topsoil, leading to catastrophic floods when heavy rains fall. Logging in the tropics destroys the forest canopy that is an essential part of regional ecosystems, alters the hydrological cycle and rainfall pattern, exposes thin, fragile soil that turns rapidly to desert, and converts warm moist tropical regions to hot dry semi-desert arid zones. Food resources, particularly protein from the sea, are in jeopardy. Predatory fishing practices have contributed to the collapse of coastal and ocean fisheries in many regions. Species extinctions, mostly as a consequence of human actions, are occurring at rates approaching those at the end of the Jurassic era 65 million years ago. Biodiversity is being reduced, partly because of monoculture methods of agricultural production. Evolutionary biology teaches us that this reduced survival chances at times of environmental stress. Genetically homogenous crops cannot adapt as readily as heterogenous crops in which some individual strains are resilient enough to withstand stress. Encroachment of human settlements into wilderness and human predation also contribute to species extinction and reduced biodiversity.

Demographic change in the twentieth century was unprecedented. A population surge quadrupled our numbers from about 1.7 billion in 1900 to 6.4 billion in 1999. This was accompanied by much migration between countries. There was huge rural-to-urban migration; peri-urban slums and shanty-towns proliferated in many parts of the developing and some parts of the developed world. Urban areas now hold around half of all humans. There has been a worldwide trend towards population aging (i.e. higher proportions surviving to old age). Cities usually arise in fertile environments, so they consume nearby farmland as they expand, reducing per capita productive agricultural

areas. Urban areas have very large and, in the long run, unsustainable ecological footprints (i.e. they depend on extensive and often distant ecosystems for essential resources to sustain them).

The huge numbers of people who have migrated from one country and culture to another have sometimes been escaping war zones, and sometimes their migrations have precipitated confrontations and armed conflicts. The twentieth century was the most violent in history, with two world wars and innumerable local and regional so-called "low-intensity" wars that collectively killed over 100 million people. Since the middle of the twentieth century, 75% or more of those killed and maimed in wars have been non-combatant women and children. Wars do enormous environmental damage, aggravated when agricultural land is depopulated by the conflict or rendered unusable by landmines, and forests are defoliated to reduce cover for adversaries.

Widespread environmental pollution of air, water, and soil with smog, toxic chemicals, effluent from untreated human and animal wastes, frequent massive oil spills when supertankers encounter adverse weather or make navigation errors, and overloaded landfill sites that contaminate ground water are symptoms and signs of a profligate consumer society lacking self-restraint. The toxic pollutants such as lead, mercury, and persistent organic chemicals are by-products and waste products of industry, or are ingredients of pesticides used to destroy plants and insects that impair agriculture or endanger health. Indiscriminate use of pesticides and antibiotics has led to the proliferation of pesticide-resistant insects and antibiotic-resistant microorganisms, and in addition new and dangerous infectious pathogens have emerged—more than 30 in the final quarter of the twentieth century. The best known is HIV, which is probably a mutant strain of a simian retrovirus. Some recently identified infections (e.g. legionnaires disease, Lyme disease, and several viral hemorrhagic fevers) are associated with human alteration of ecosystems.

Globalizing industrial economies are claimed to be a panacea for the relief of poverty—an assertion that so far lacks proof—but even if they are, the wealth could prove evanescent because many transnational corporations have a predatory attitude towards natural resources. The capital value of all resources extracted from the earth is calculated to be in excess of US$22 trillion per annum. It is unclear how long this annual drain on the global commons can continue before it puts the sustainability of global and regional ecosystems in jeopardy. World cultures are homogenizing and perhaps becoming less perceptive, less engaged in important public issues, due to the pervasive influence of intellectually vapid television. Political systems are volatile, so elected officials are often reluctant to make unpopular decisions (e.g. imposing deterrent taxes on the use of fossil fuels). Tax revolts and a preference for electing governments that campaign on promises of further tax cuts erode essential infrastructure for water purification and similar environmental health protection measures. Political volatility has a detrimental effect on election campaigns and on those elected to serve the people: few are willing to plan with a time horizon further away than the beginning of the campaign season for the next election. Yet the state of the world requires planning with a time horizon of 50 to 100 years.

All these factors and several other global changes have an impact on human health and

must be considered in context with global climate change. Some of the adverse consequences of climate change for human health occur because several of these factors act synergistically (i.e. reinforce each other and make matters worse than if each factor acted separately).

3. Stratospheric Ozone Depletion

UVR is an ingredient of solar radiation, and the stratospheric ozone layer, situated at an altitude of between 12 km and 45 km, protects all life forms against significant levels of overexposure to this potentially harmful form of radiation, and especially the most dangerous and biologically active radiation at the shortest end of the UV spectrum. In 1974, research by F.S. Rowland and M.J. Molina, two atmospheric physicists, led them to predict that seemingly inert lighter-than-air chlorofluorocarbons (CFCs) would permeate the upper atmosphere where solar radiation would break them down to produce chlorine monoxide, which would destroy the protective ozone layer shielding the biosphere from lethal levels of exposure to UVR.

Each molecule of chlorine monoxide is capable of destroying 10 000 ozone molecules. (Other ozone-destroying substances (ODSs), notably fertilizers containing bromine compounds that have been widely used in rice cultivation, are also implicated.) Empirical observations have confirmed Molina and Rowland's prediction. In the Southern Hemisphere spring of 1985, J.C. Farman and her colleagues observed a large region of attenuation (generally known as the "hole") of the ozone layer over Antarctica. Observations since 1985 have demonstrated that this was not a transient phenomenon. Although the extent of attenuation fluctuates, the trend has been towards expansion of the affected region. In the Southern Hemisphere spring of 2000, the extent of the hole was greater than ever previously observed. The thinning of the ozone layer reaches its peak in late winter and early spring, but it persists year round. Rowland and Molina were awarded the Nobel Prize for physics in 1995 in recognition of their work.

Observations of the thickness of the ozone layer and of UVR flux at the earth's surface from many parts of the world, in urban and rural regions, high mountains, mid-ocean readings from marine observation stations, and from high altitude balloons, and satellites in space, all confirm that generalized thinning of the ozone layer and elevation of UV radiation flux are occurring.

Since systematic observations began in the mid 1980s, there has been a generalized reduction of stratospheric ozone by about 2% to 3% as well as regional and seasonal attenuation. The extent varies. It is generally greatest in cold seasons in those parts of the world with cold climates (i.e. Siberia, and northeast North America in the Northern Hemisphere). In the Southern Hemisphere, the high latitudes of Chile and Argentina and the south of the south island of New Zealand are the worst affected populated regions. Measurements of UV radiation flux at the earth's surface show a close correlation between attenuation of the ozone layer and elevated levels of UV radiation flux. Because of the long half-life of CFCs, attenuation of stratospheric ozone will persist for at least until the end of the twenty-first century before any perceptible improvement occurs.

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Biographical Sketch

John M. Last was born and educated in Australia. He graduated from the University of Adelaide medical school in 1949. After five years of hospital training and five years in general practice, interspersed with intercontinental voyages as a ship's surgeon, he specialized in public health and epidemiology. He has worked as an epidemiologist and educator in Australia, England, Scotland, the United States, and for WHO and other agencies in Colombia, Indonesia, India, Sri Lanka, Singapore, Thailand, China, Saudi Arabia, Pakistan, and Kuwait, and for WHO Headquarters in Geneva. He has held academic positions with the British Medical Research Council in London, at the Universities of Sydney, Vermont (USA), and Edinburgh, and has been professor of epidemiology and community medicine at the University of Ottawa since 1969. He was the editor of the eleventh, twelfth, and thirteenth editions of *Public Health and Preventive Medicine* and editor emeritus of the fourteenth edition ("Maxcy-Rosenau-Last"); editor of the first, second, third, and fourth editions of the *Dictionary of Epidemiology*, and author of the first and second editions of *Public Health and Human Ecology*. He was the scientific editor of the *Canadian Journal of Public Health* (1981–1991), the editor of *Annals* of the Royal College of Physicians and Surgeons of Canada (1990–1997), and has served as editor or a member of the editorial board of several other medical journals. He is one of three editors of the third edition of the *Oxford Illustrated Companion to Medicine* (June 2001) and one of the five editors of the Macmillan *Encyclopaedia of Public Health* (2001). He is the author of chapters in 45 books and over 200 original articles in journals of medicine and science.

Dr. Last was president of the American College of Preventive Medicine (1987/89), Canadian vice-president of the American Public Health Association (1988/89), and has held office in several other national and international professional colleges and associations. He is an honorary life member of the Society for Social Medicine (U.K.), the International Epidemiological Association, and the American College of Epidemiology. His recent awards include a Rockefeller Foundation visiting scholar appointment at the Villa Serbelloni, Lake Como, Italy; an honorary M.D. from Uppsala University, Sweden; the Special Recognition Award of the American College of Preventive Medicine; the Duncan Clark Award of the Association of Teachers of Preventive Medicine (for contributions to preventive medicine); and the Abraham Lilienfeld Award of the American College of Epidemiology (for contributions to epidemiology).

Dr. Last's principal research interests are in the sustainability of human health in environments and ecosystems that are becoming less sustainable, and aspects of medical ethics that relate to public health and epidemiology.