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EDITORIAL

Global climate change, widening health inequalities, and epidemiology

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The most recent report from the United Nations' Intergovernmental Panel on Climate Change (IPCC) provided compelling evidence on the effect of human release of greenhouse gases from fossil fuels and deforestation on the global climate change.[1] The IPCC estimate that since the mid-19th century there has been an increase in average temperature of 0.6°C, most of this increase occurring at the end of 20th century. In addition, it provides evidence of changes in the patterns of precipitation, aridification, and humidity. Events occurring since the publication of the IPCC report in 2001 have added substantial new evidence. The average concentration of carbon dioxide has reached 375 p.p.m. (almost 100 p.p.m. above the interglacial levels) (Figure 1); polar and alpine ice is melting at faster rates than expected[2] and mean sea level has been observed to rise by ~30 cm during the 20th century.[3] Circumpolar winds are accelerating, probably intensifying the El Niño/Southern oscillation with increasing flows in Southern Asia, South-east Africa, South-east USA, or Central America and a large increase in the number of hurricanes reaching categories 4–5 on the Saffir–Simpson scale has occurred in the last 15 years.[4] The IPCC projections forecast rises in temperature between 1.4 and 5.8°C by 2100, elevation in mean sea level of 9–88 cm,[1] and increases in heatwave frequency of 25–31%.[5]

Health effects

These effects of rising temperature, altered storminess and hydrologic extremes occur in the context of a high population growth rate. Many land areas that are now occupied were barely inhabited in the past owing to potential climate-related risks. Thus, at present most climate oscillations involve direct threats to human communities, whereas in the past the number of individuals affected was small both in absolute and relative terms. There is mounting evidence that climate change may already be affecting human health including mortality from heat, cold, or climate disasters; changes in air and water quality; and changes in the ecology of infectious diseases.[6] The World Health organization (WHO) has estimated that the warming and precipitation trends due to anthropogenic climate change in the last 30 years of the 20th century already claim over 150 000 lives annually,[7] although the study was made under generally conservative assumptions about climate–health relationships.[8]

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Effects of temperature

The summer of 2003 was the hottest in 500 years in Europe with average temperatures 3.5°C above normal.[9] The impact of a 2 week heatwave occurring during that summer was 22 000–45 000 extra deaths,[10] which reflects the health risks of extreme events due to climate change and shows that climate change was outside the expected range of variability.[11] Heat mortality follows a U shape dose–response function with increased mortality in both extremes (cold and heat). The safest temperatures vary between areas probably because of an adaptation process since the greatest effects of hot days occurred in early summer presumably because of the large relative increase in temperature values rather than in the absolute temperature.[8] Although most of the studies on the effects of temperature have been done in cooler regions, the heat effects may also appears in cities with subtropical conditions.[12] Changes in land cover and the urban 'heat island' effect may exacerbate the effect of the greenhouse gases at local level. The displacement of temperature curves may mitigate the effects of cold in the future due to the general warming,[6] but the increase of extreme events may increase both cold-related and heat-related mortality episodes. What probably is more notable from the public health perspective is the sociological analysis of the health impact of the Chicago heatwave occurring in 1995 that mostly affected 'socially isolated' persons and claims that sociologically vulnerable people are the most affected by meteorological extremes.[13] However, a larger effect in frail people has not been found for the European 2003 heatwave.[14]

Effects of rainfall

Regional famines due to disruption of food production because of climate change has been well recognized owing to changes in growing season, altered patterns of precipitation, altered plant pathogens, and reduced soil moisture due to warmer temperatures, particularly in mid-continental and semi-arid regions.[15] Malnutrition, particularly in subtropical regions, might then be a very likely endpoint of climate change exacerbating food supplies inequalities mainly in Africa.[6]

Effects on disease vectors

Climate change has a demonstrated effect on infectious diseases because of changes in their ecology. Infections agents and the physiology of their associated vectors are affected by temperature,[16] and geographical associations between climate

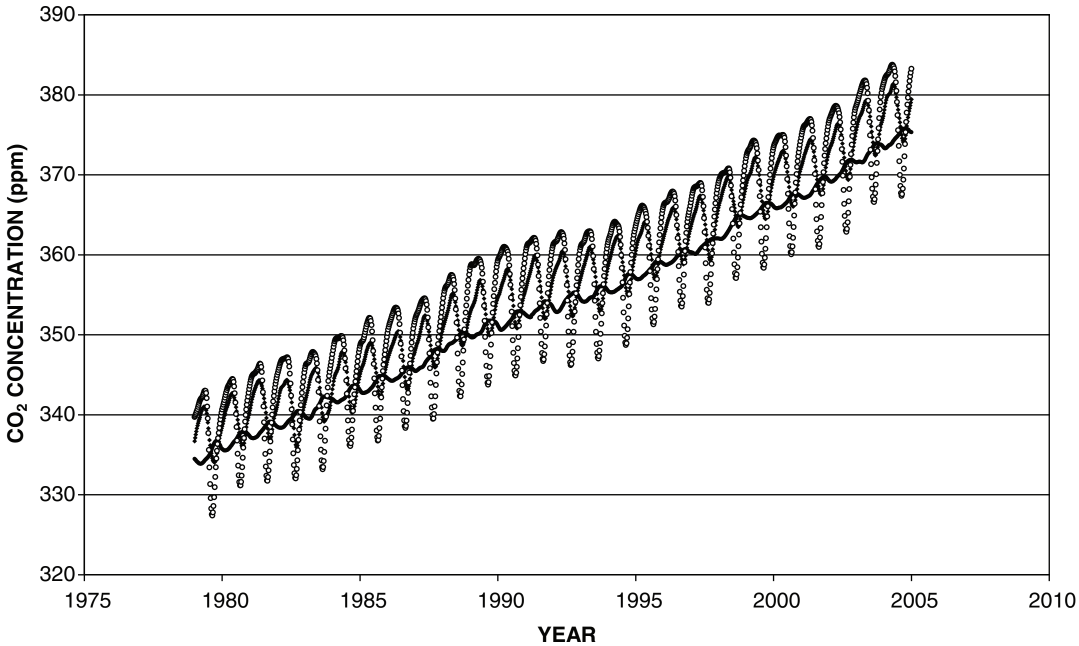

Figure 1 Changes in CO_2 concentrations measured in Antarctica, Hawaii, and Alaska. Data from GLOBALVIEW-CO_2, 2005 (www.cmdl.noaa.gov/ccgg/globalview/co2/)

Table 1 Outcomes considered and assumptions in the model-based forecast undertaking by the World Health Organisation[6]

Outcomes considered:

(1) Direct effects of heat and cold on incidence of cardiovascular disease deaths;

(2) Food-borne and water-borne diseases on incidence of diarrhoea;

(3) Vector-borne diseases on incidence of malaria cases;

(4) Natural disasters on incidence of death due to unintentional injuries;

(5) Risk of malnutrition.

Assumptions:

(1) Mechanisms of reduction of greenhouse gases

(2) Population growth

(3) Adaptation and vulnerability

variables and the distribution of mosquito-borne diseases have been shown for dengue fever[17] and malaria.[18] The association with malaria, however, remains controversial owing to the difficulty of controlling for demographic and drug-resistance data.[19] Other infectious diseases, such as salmonellosis in Europe, Ross River virus in Australia, and plague and cholera in the American south-west have been related with changes in temperature, while epidemics of Rift valley fever in East Africa, Hantavirus pulmonary syndrome and cholera in the American south-west and Bangladesh have been related with rainfall changes.[8]

Modelling climate-health associations

Based on modelling, WHO has made forecasts of the climate–health relationships projected to 2030, using as baseline conditions the period 1961–90.[6] The effects on thermal extremes and weather disasters considered are shown in Table 1. The effects on emergence of new pathogens, the distributions of agricultural pests and pathogens, destruction of public heath infrastructure, and the production of photochemical air pollutants, spores, and pollens were potential mechanisms not considered. The analysis suggested that climate change will bring some health benefits, such as lower cold-related mortality and greater crop yields in temperate zones, but these will be greatly outweighed by increased rates of infectious diseases and malnutrition concentrated in poorer populations at low latitudes (half of the cases in Africa) where the most sensitive climate-related health outcomes (diarrhoea, malaria, and malnutrition) are already common and where vulnerability to climate effects is greater.[6] Data from the Mapping Malaria Risk in Africa project applying global climate projections determined an increase of 16–28% in person-months exposure to malaria risk by the year 2100.[21] Overall, although Africa has the lowest emissions of greenhouse gases (Figure 2) it could suffer the greatest burden of climate-sensitive diseases increasing inequalities in health.

The role of epidemiology

In this possible scenario, what is the role of epidemiology beyond that of lobbying for mitigation of anthropogenic greenhouse gases and deforestation?

(i) To continue documenting the associations between climate change and health outcomes more specifically both in terms of exposures and outcomes, and in a wider range of datasets and locations to provide more precise and convincing evidences.

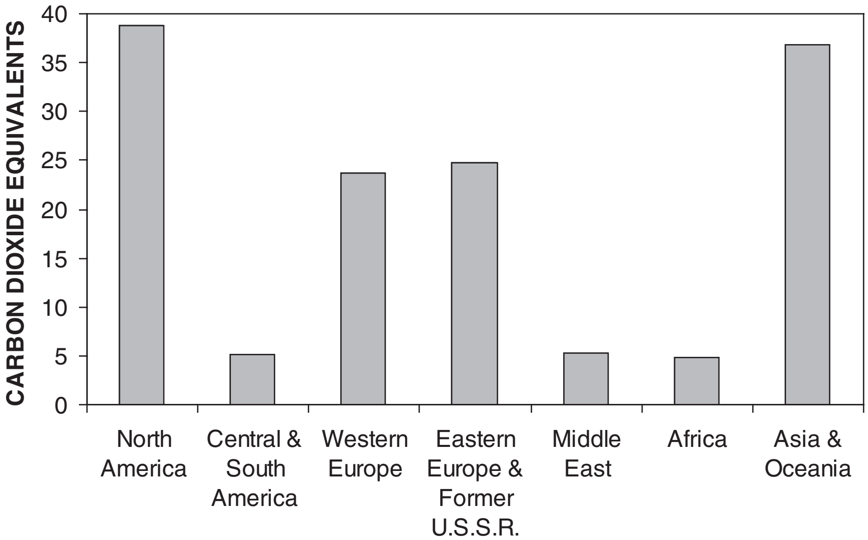

Figure 2 Accumulated emission of green house gases between 1980 and 2003 (in CO_2 equivalents; billion of metric tons). Data from International Energy. Related environmental information (www.eia.doe.gov)

(ii) To create a 'forward' epidemiology as described by Anthony McMichael in the last conference of the International Society of Environmental Epidemiology (ISEE). In other words, conduct research on future scenarios based on advanced modelling, applying projections at local or regional level downscaling the current projections and dynamics based on several climate models; relating climate and health with a broad range of socioeconomic environments; carry out validation studies of the projected future scenarios based on empirical data; and obviously, perform classical longitudinal studies on present and past patterns on a broad range of health effects due to climate, particularly in subtropical regions.[6]

(iii) To create city specific 'Early warning systems' such as the weather-watch warning system based on climate-based models to predict the occurrence of heatwaves such as those set up in Rome and a few other cities.[22] This system has already allowed taking preventive actions including health services plans that have reduced notably the impact on health. Intervention plans may also be undertaken after early predictions of events such as hurricanes or flooding particularly in developing countries (but also in the poor areas of the developed world).

(iv) To implement vector-borne disease control programmes based on interventions developed using risk-assessment and cost-benefit technologies. These procedures should incorporate existing knowledge on, for example, resistance of mosquitoes to insecticides or long-term effects of low doses of pesticides, as well as environmental actions, and therapeutic plans and other health interventions strategies of proven efficiency. Also, to boost research on primary prevention of vector-borne diseases through control of the ecology of mosquitoes or vaccination.

(v) To promote the epidemiology of malnutrition at the same level as the epidemiology of obesity, including concepts such as food distribution and equity.

(vi) Finally, to examine the upstream determinants of climate change as part of broader health impact assessments associated with environmental (e.g. agricultural, forestry, transport, etc.) changes.

Conclusion

Projections of the global health effects due to the global climate changes signal a massive impact on the less favoured parts of the world. Epidemiology should play a role in predicting and preventing additional effects in human populations already affected by the common diseases vulnerable to global change such as diarrhoea, malaria, and malnutrition. Africa, with the lowest emission of greenhouse gases, could suffer the greatest health impact.

References

[1] Intergovernmental Panel on Climate Change. Climate change 2001: impacts, adaptation and vulnerability: contribution of Working group II to the second assessment report of the IPCC. McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (eds). Cambridge: Cambridge University Press, 2001.

[2] Hassol SJ. *Impacts of a Warming Arctic: Artic Climate Impact Assessment*. Cambridge, England: Cambridge University Press, 2004.

[3] Kearney MS, Rogers AS, Townshend JRG, Rizzo E, Stutzer D, Stevenson JC *et al*. Landsat Imagery Shows Decline of Coastal Marshes in Chesapeake and Delaware Bays. *Eos Transactions* 2002;**83:**173.

[4] Webster PJ, Holland GJ, Curry JA, Chang H-R. Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* 2005;**309:**1844–46.

[5] Arnell NW. The consequences of CO_2 stabilisation for the impact of climate change. *Clim Change* 2002;**53:**413–46.

[6] McMichael AJ, Campbell-Lendrum D, Kovats S, Edwards S, Wilkinson P, Wilson T *et al*. Comparative quantification of health risks: global regional burden of diseases due to selected major risk factors. Ezzati M, Lopez AD, Rodgers A, Murrgay CJL (eds). Chapter 20. Geneva: WHO, 2004, pp. 1543–649.

[7]The World Health Organisation. *The World's Health Report 2002*. Geneva: WHO, 2002.

[8]Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. *Nature* 2005;**438:**310–17.

[9]Luterbacher J, Dietrich D, Xoplaki E, Grosjean M, Wanner H. European seasonal and annual temperature variability, trends and extreme since 1500. *Science* 2004;**303:**1499–503.

[10]Kosatsky T. The 2003 European heat waves. *Euro Surveill* 2005;**10:**148–9.

[11]Schar C, Vidale PL, Luthi D, Frei C, Haberli C, Linger MA *et al*. The role of increasing temperature variability in European summer heatwaves. *Nature* 2004;**427:**332–36.

[12]Gouveia N, Hajat S, Amstrong B. Socioeconomic differentials in the temperature-mortality relationship in Sao Paulo. *Int J Epidemiol* 2003;**32:**241–51.

[13]Klinenberg E. *Heat Wave a Social Autopsy of Disaster in Chicago*. Chicago: Chicago University Press, 2003.

[14]Holstein J, Canoui-Poitrine F, Neumann A, Lepage E, Spira A. Were less disabled patients the most affected by 2003 heat wave in nursing homes in Paris, France? *J Public Health* 2005;**27:**359–65. Epub 2005.

[15]McMichael AJ. Impact of climatic and other environmental changes on food production and population heath in coming decades. *Proc Nutr Soc* 2001;**60:**195–201.

[16]Epstein PR, Diez HF, Elias S *et al*. Biological and physical signs of climate change: focus on mosquito-borne diseases. *Bull Am Meterol Soc* 1998;**78:**409–17.

[17]Hopp MJ, Foley JA. Worldwide fluctuations in dengue fever cases related to climate variability. *Clim Res* 2003;**25:**85–94.

[18]Rogers D, Randolph SE. The global spread of malaria in a future warmer world. *Science* 2000;**289:**1763–66.

[19]Hay SI, Cox J, Rogers DJ, Randolph SE, Stern DI, Shanks GD *et al*. Climate change and the resurgence of malaria in the East African highlands. *Nature* 2002;**415:**905–09.

[20]Epstein PR. Climate change and human health. *N Eng J Med* 2005;**353:**1433–36.

[21]Tanser FC, Sharp B, Sueur D. Potential effect of climate change on malaria transmission in Africa. *Lancet* 2003; 362:1792–98.

[22]Michelozzi P. Impact of heatwaves on mortality-Rome, Italy, June–August 2003. *Morb Mortal Wkly Rep* 2004;**53:**369–71.