Health effects of climate changes: the unmet need for mitigating and adaptive measures

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Abstract

Purpose: This paper outlines the health effects of climate changes. Mitigating and adaptation measures are identified and proposed. These measures highlight the urgent need for action.

Methods: This is an extended literature review paper based on keywords search: direct and indirect climate change health effects, uncertainty about climate changes, vulnerability, and adaptation and mitigation measures.

Results: Climate changes can negatively affect human health both directly, e.g., through extreme weather events and outbreaks of climate sensitive diseases such as malaria and dengue fever, and indirectly, e.g., through food and water insecurity issues. Climate changes and their health impacts can only be predicted within wide margins of uncertainty. A precautionary approach and the complementary responses of adaptation and mitigation are proposed dealing with the health risks of "global warming".

Conclusions: Current climate change increasingly evolves as a major health risk and an important challenge to deal with. The changing climate and the severity of the health impacts reveal the urgent need to act and adopt mitigating and adaptation measures. Addressing environmental health in plans dealing with climate changes will result in benefits for natural environment, human and animal health.

Keywords

Environmental health, greenhouse gases emissions, sea level rise, pedestrianization, green areas, planning

Introduction

The Earth's climate system changes continuously: cool and warm periods alternate, but the current warming is unusual [1, 2]. This trend phenomenon is attributed to human activities and to the continuously increasing demand for energy [1]. The strong relation between climate and health is undisputed [3-5] and the roots of that knowledge dovetail in the ancient years. For instance, the Greek physician Hippocrates described 2,400 years ago connections between health and environmental quality in his work "On Airs, Waters, and Places" [6].

Negative influences on the climate result from air pollution and affect water quality [7, 8]. Greenhouse gas (GHG) emissions cause the warming while aerosols have mainly a cooling impact, moderating the heating process [7]. Surface water layers stock massive amounts of the energy resulting from the warming climate. Their physical and biological characteristics change in a significant way [see e.g., 4, 5]. GHG act as drivers of climate changes (CC). This contributes to or causes floods, heath waves and other extreme weather events [1, 7, 8]. The changing weather patterns also influence agriculture, food, water, ecosystems and socioeconomic conditions, which all can affect health [3].

The warming of the planet is a global threat for human health [4] and dealing with unfavorable climate conditions is an urgent need. Climate change has started downgrading the quality of everyday life of many people and its potential impacts on health are severe and should be addressed with attention. Extreme weather events, such as hurricane Katrina and storm Xaver, revealed that humanity should be protected more effectively against extreme weather phenomena. Natural disasters cause injuries and deaths, devastate the socio-economic situation [4, 9-11], degrade the natural environment [12, 13], and cause a variety of health problems, including water and food borne diseases, and climate sensitive diseases that are often difficult to treat such as malaria, Lyme disease or dengue fever [3].

The low urban air quality in combination with noise, the heat island effect and other factors has turned modern megacities in almost hostile places to live in. This illustrates their urgent need of in depth remodeling, moving to more sustainable conditions [14,15]. City designers and policy makers have to deal with air pollution, urban warming [14, 15] and with the resilience of the urban environments which should offer security also towards unfavorable weather events and their impacts. Vulnerability to climate change shows significant variation between social classes, and between poor and prosperous countries [16-19]. Moreover, the effects of the CC are unequally distributed [3], making the CC landscape even more complex.

Science cannot predict exactly the future climate outcomes and the existing scenarios and forecasts are characterized by inherent uncertainties [20]. Only carefully planned strategies which do not deal with scientific uncertainty justifying inertia can effectively protect people from the imminent climate risks. An integrated approach cannot be realized unless "environmental health" is at the center of the concerns. The pathway towards a cleaner and safer planet begins with proper mitigating and adaptation strategies. The aim of this contribution is outlining the health effects of climate changes, propose mitigating and adaptive measures as steps leading to a healthier tomorrow and highlight the urgent need for action.

Current climate change

The global average temperature at the Earth's surface increased by 0.74 ± 0.18 °C during the 20th century (1906 – 2005).

During the same period heat waves became more frequent and intense. Also increases in sea level (mainly attributed to the thermal expansion of the surface water and the melting of the polar land ice), precipitation, drought, changes in the frequency and intensity of monsoons and tropical cyclones, unexpected variations in snow cover, and alterations in the atmospheric circulation and in the ocean water streams were recorded [21]. Many of the last years are ranked amongst the hottest ones on record of the last centuries. For instance 2010, was the hottest year, 2005 the second, 2003 the fifth and 2012 the ninth hottest year since 1850 [22]. Warming will continue during the near future because it is the result of greenhouse gas emissions in the past [23]. By the end of the 21st century a temperature increase of 1.1 to 6.4°C is forecasted [21]. More negative impacts are expected and there is an urgent need to adopt adaptation and mitigation measures.

Climate changes also affect ecosystems and the consequences impact both terrestrial (e.g.,, effects on biodiversity [24] and aquatic ecosystems (e.g.,, negative effects on coral reefs [25]). Humans rely on ecosystems for many of their essential needs and therefore their well being is threatened.

Direct health effects of climate changes

As weather affects human health directly, changes in climate affect health also in a direct way [e.g 3-5, 26, 27].

Air quality

Continuous emissions mainly during the last half a century degraded the air quality affecting both the climate system and human health. Polluted air contains among others, GHG, particulate matter (PM), aero-allergens, radioactive elements, desert dust (the dust can be mixed with pollutants such as PMs and mold spores) and other pollutants [28-30]. GHG increase the intensity of the "greenhouse effect" and chlorofluorohydrocarbons (CFCs) cause the depletion of the stratospheric ozone layer, allowing more ultraviolet radiation to reach the Earth's surface. Others pollutants increase tropospheric ozone concentrations, indicating elevated exposure to a complex mixture of pollutants [7]. Exposure to ultraviolet radiation increases the risk for melanoma and other cutaneous malignancies, cataracts and immunosuppression [31, 32].

Weather conditions affect air quality and CC play a determining role in that impact [33]. For instance, increased temperatures promote the formation of tropospheric ozone [34, 35]. Furthermore, CC causes alterations in the normal production of pollen [3]. Cardiovascular and respiratory diseases can be attributed to air pollution. Pneumonia, asthma, chronic obstructive pulmonary disease, allergic rhinitis are common examples. Furthermore, air pollution leads to increased mortality [3]. Air transport of pollutants from remote areas, wildfires, wood smoke from fireplaces and burning of inappropriate materials make the problem more complex.

Outdoor air quality can be low, offering a risk as the total population might be exposed to it during long periods. However, poor indoor air quality is also related to weather and CC. To reduce GHG emissions and save energy (mitigation measures) people effectively insulated many buildings. In the absence of sufficient ventilation, insulation leads to the deterioration of the indoor air quality [34]. Avoiding the sick-building syndrome needs an anticipative and precautionary attitude from architects and building designers should be aware of the importance of the construction in establishing both energy efficient and healthy indoor environments.

Extreme weather conditions

Extreme weather events often cause natural disasters of which the impacts are devastating. Examples include heat waves, typhoons, hurricanes, floods and droughts. The consequent natural disasters are attributed to (intensified) CC [36]. Extreme weather conditions have multiple health impacts. Next to common health impacts, extreme weather conditions cause injuries, deaths, respiratory, cardiovascular and diarrheal diseases. The psychological impacts of the natural disasters are sometimes most destructive (e.g., the loss of relatives and / or property). Post-traumatic stress includes anxiety, depression, and unusual behavior, especially in children [37, 38]. Mental health problems must not be underestimated and authorities should offer psychological support where needed. In the center of the Belgian port city of Antwerp, the average temperature during summertime is 3.5°C higher than in the rural areas surrounding the city. In Antwerp's parks the effect is 1°C less as compared to the built areas. This shows that greening the city in innovative ways, is the main reply to the urban heat islands.

High temperatures and heat waves

High temperatures are associated with an increased incidence of many health problems, including heat exhaustion, heart and brain failure, stroke, cramps and diarrheal disease [3-5, 39]. Temperature changes alter the geographical and seasonal distribution of climate sensitive diseases, such as malaria and schistosomiasis. High temperatures enhance the negative effects of the air pollution [40]. Furthermore, the formation of the urban heat island effect leads to higher temperatures in many cities, which increases the health risk [3, 14, 41].

Water born disease vectors and parasites are adapted to the temperatures and the humidity in the areas where they prevail. When the climate conditions change, the areas where these organisms breed [42, 43] and the corresponding odds of infection change. For instance, malaria which is caused by the parasite Plasmodium falciparum is transmitted by the Anopheles mosquito. This insect does not survive below 20ºC [44] and the optimum temperature range is 25-30ºC [42]. Changing climate conditions will affect in this way the incidence of infected people.

Heat waves during summer months and heat-related deaths became common while deaths from excess cold still remain a significant fatal factor in the northern and continental regions of Europe [3]. Most characteristic is the excess mortality during the summer heat wave of 2003 in many European countries. In France, mortality during this period reached record levels (about 14,800 victims) [45]. In 12 affected European countries 70,000 excess deaths were registered [46]. Another example are the approximately 1,000 excess heat wave deaths in Athens in July of 1987 [47]. Respiratory and cardiovascular morbidity, stroke and mortality are outcomes of the exposure to extreme heat [3-5, 48]. Elderly people, people with chronic diseases and people who are under certain diuretic medications belong to the most vulnerable groups. Their health problems are caused by the difficulties they experience in regulating their body temperature [48].

Heath waves are increasing in frequency and intensity in Europe [1]. In the absence of an effective mitigation policy, countries increasingly focus on adaptation measures. These include early warning systems, extreme weather event action plans and disaster preparedness and response mechanisms. Additional attention should be given to climate-resilient health care infrastructure.

Floods and heavy precipitation

Floods are the most common example of natural disasters [49] which affect thousands of people annually. Injuries and deaths are common during flood episodes [3].

Floodwaters transport microorganisms, chemicals and materials causing infections and injuries. Contamination of natural water bodies or drinking water frequently occurs [3, 50]. Contaminated floodwater may contain heavy metals, pesticides, asbestos and radioactive waste depending on the nature of the flooded sites [50]. Molds can contaminate flood-affected houses and other humid buildings. Moreover humidity in houses is difficult to treat [51]. Consequently inhabitants can be exposed to microorganisms, mycotoxines, VOCs and various airborne PMs, which increase the risk for respiratory diseases and cancer [52, 53].

Floods are mainly related to fecal-oral diseases (e.g., cholera, typhoid fever, cryptosporidiosis, non-specific diarrhea), vector borne diseases (e.g., malaria, West Nile virus) and rodent borne diseases (e.g., Hantavirus Pulmonary Syndrome, leptospirosis) [49].

Heavy precipitation favors the development of breeding sites for vectors such as mosquitoes (e.g., malaria, dengue fever), ticks (e.g., encephalitis, Lyme disease), rodents (e.g., leptospirosis, hantavirus pulmonary syndrome) and snails (schistosomiasis) [3, 54].

Tropical cyclones

Tropical cyclones (hurricanes, typhoons, cyclones) cause millions of deaths and are associated with a variety of health impacts including injuries and infectious diseases (e.g., malaria, typhoid fever, infectious hepatitis, gastroenteritis and acute respiratory infections) [55]. Floods produced by tropical cyclones, heavy rainfalls, strong winds and storms are destructive and result in a variety of above mentioned health risks, including the contamination of natural water bodies [3].

Droughts

Droughts are associated with malnutrition, respiratory problems (airborne dust) and infectious diseases, with the meningococcal meningitis being one of the most characteristic examples [3, 56]. Droughts also increase the risk of (forest) fires [56] which also constitutes a health risk factor. Any stagnant water body is a suitable environment for pathogenic agents, such as toxic algae [e.g., 57].

Indirect health effects of CC

Climate change is related to indirect health impacts which are affected by changes in the Earth's climate. For instance, CC produce food and water insecurity resulting in economic decline [3, 4]. In view of the fast increasing population in many developing countries [4, 58], these issues are of paramount importance.

Sufficient food of good quality is basic in avoiding food insecurity and the associated negative health impacts. Adequate quantity is threatened by extreme weather events (e.g., floods, droughts) and water scarcity, leading to under- and malnutrition resulting among others in micronutrient deficiencies [3, 4]. Inadequate food quality may result from increased temperatures affecting the breeding and development of infectious organisms. Flies, rodents and toxic algal blooms provide characteristics examples [3]. Increased ocean temperatures (which are an effect of CC) favor the development of aquatic plants able to produce toxins which expose humans through the food chain (e.g., consumption of contaminated seafood or contact with contaminated bathing water). A common example is ciguatera. Furthermore, ocean warming favors the methylation of mercury. The result is increased exposure to methyl mercury through fish consumption [3].

Reassurance of safe and enough water is not for granted. The poor quality of salinized irrigation water (likely due to sea level rise as a result of CC or due to over-irrigation) and / or the lack of the necessary water for agriculture can reduce the yield of many crops and appears as an important cause of food insecurity [9, 59, 60].

Poor sanitation is a risk factor for the development of many diseases and related, influencing factors, such as already poor sanitation, overcrowding, unequal distribution of natural resources and poverty which all contribute increasing the vulnerability to climate sensitive diseases [4, 9, 61]. Water-borne diseases cannot be avoided when hygienic conditions are substandard and where there is insufficient access to safe drinking water [3]. CC influence both prerequisites and consequently increase the vulnerability of people.

Poverty can increase as a result of CC [11]. Natural disasters, contribute to economic collapse [see 4, 10, 62]. Natural disasters trigger population displacements and host communities face increased risks of overcrowding, food and / or water security, communicable diseases and violent conflicts [9, 11].

CC change energy consumption patterns and extreme temperature events may lead to increased energy needs for cooling or heating [63]. This is well documented in relation to the urban heat island effect [64]. Biofuels are considered able to counteract the increasing greenhouse gas emissions [65, 66]. Biofuel crops need land and water which otherwise can be used to produce food in particular for poor and vulnerable populations [65]. In this way, biofuel crops contribute to food insecurity.

Vulnerability to CC

"Vulnerability is "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." [67].

Vulnerability is about the social dimension of the CC, because the poorest (low or zero income) and other social groups, such as elderly, children, sick, marginalized and homeless people, are more susceptible to CC and to extreme weather conditions [68]. CC aggravate social inequity and factors such as social class, gender, age, ethnicity, political decisions determine the intensity of the impact [68, 69]. Capacity to adaptation is a key element of vulnerability. Even within the same geographical area (e.g., in a city), the adaptation capacity extremely differs among social groups. Obviously, certain groups (including sick people) face higher risks from the same extreme weather events than the more privileged ones [68-70]. Areas which are (highly) vulnerable include many developing countries and coastal regions [3, 4]. An example is provided by the developing small-island states. For them a natural disaster or the coral deterioration that can be attributed to CC [25, 71], results in subsequent declines in the income from fishery and tourism [70]. The more economic degradation, the more difficult it is for these states to obtain an appropriate level of protection against CC. More in general, geographical location is an important risk factor for vulnerability and all coastal regions face adverse effects as a result of sea level rise and storms [72]. Other risk factors result from anarchic urbanization and especially from the emergence and existence of "slums", i.e. the vast informal settlements characterized by overcrowding, lack of sanitation and of safe water (probable causes of diarrheal diseases) and many other socioeconomic and health related problems [4, 73].

The most vulnerable groups are not or under-represented in decision-making. This concerns both whole countries and social groups. This increases their vulnerability and limits their adaptive capacity [69, 70, 74]. Decision making should take into account a socially fair burden sharing of the CC risks and avoid making the already vulnerable even more susceptible to CC [74].

Vulnerability is a function of factors changing over time and space. Vulnerability is not static [75] and requires continuous efforts to determine and manage its real dimensions.

Uncertainty

Different climate scenarios and forecasts allow predicting climate behaviour, but all of them are characterized by inherent uncertainties [20, 76]. Part of this uncertainty is about predicting (the extent of) the health outcomes. Health outcomes are the result of complex interactions between climate, environmental policies and adaptation and mitigation measures, population growth, socio-economics to mention just these aspects. This multi-causality and the resulting complexity make predictions uncertain [3]. A primary uncertainty is related with the average increase in temperature which is forecasted for the end of this century and which ranges between 1.1 and 6.4ºC [21]. However, an increase of a few degrees above a threshold during summertime will cause a significant number of excess deaths [45, 77]. Therefore, even a slight increase in temperature might result in significant effects. Moreover the range of the mathematical uncertainty by itself constitutes a risk.

In spite of the uncertainties, convincing evidence exists which indicates that heat morbidity and mortality will increase with increasing temperature. The geography and incidence of climate sensitive diseases will change worldwide [3].

Underestimation of the importance of the uncertainty increases the vulnerability which, as mentioned above, changes from one period to another [17, 75]. For instance, infrastructure designers should take uncertainty about climate outcomes into account. Climate conditions are expected to be very different after every 80 to100 years while the life expectancy of the build infrastructure exceeds that time period [78]. This illustrates that the adaptive capacity decreases over the years, while vulnerability increases. Decision-making has to address the uncertainty about the upcoming environmental and health outcomes. The vulnerability of future generations depends on the decisions taken now. Mistaken environmental and / or health related options are a threat to sustainable development.

Effective adaptation strategies can be developed even if science is not able to accurately predict the natural phenomena [79]**.** If policy makers use scientific uncertainty as a justification for inertia or for acting at an inappropriately low level, lack of preparedness and health hazards are likely results [80]. Furthermore, the nature of the adaptation and mitigation measures (e.g., clean technology, energy efficiency) increases the overall uncertainty, as the necessary degree of these measures cannot be determined exactly and only estimations are possible [1].

Decision makers have to deal with uncertainty and only a precautionary attitude can prevent and; if possible, reverse negative health trends. According to United Nations Framework Convention on Climate Change (1992) [81]:

"The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, *lack of full scientific certainty should not be used as a reason for postponing such measures*, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socioeconomic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors. Efforts to address climate change may be carried out cooperatively by interested Parties."

Strategies that should be adopted must apply the precautionary principle, decrease vulnerability and increase adaptive capacity. However, measures such as the increase of energy prices, e.g., through additional taxes, have a counterproductive capacity [82] and negatively affect both health and climate (e.g., through the use of cheap and low quality energy sources which increase the air pollution.

Mitigation and adaptation to CC

Counteracting the negative health effects of CC necessitates both mitigation and adaptation measures [1, 3, 4]. According to the glossary used by IPCC [67], mitigation is defined as:

"An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.

and adaptation, as:

"Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."

Mitigating measures are about reducing GHG emissions and counteract in this way the fundamental drivers of CC. Mitigation necessitates a policy of which also health will benefit as a result of the reduction of pollutant emissions, a more efficient use of resources, and an enhancement of GHG sinks which absorb these gases and remove them from the atmosphere [1, 3, 4, 83]. Adaptation is about coping with CC effects as sea level rise, dryer climate, surface and ground water levels, wildfires and extreme weather events [1, 3, 17, 75]. Poverty, social problems, lack of understanding the problem and its seriousness, lack of planning, of policy and of know-how are common constraints to achieve adaptation interventions [8, 68, 70]. These obstacles reveal the ability of developed countries to adapt more effectively as compared to the developing ones [4, 18]. Furthermore, adaptation entails new treats to human health and some of them also offer opportunities improving health [1, 3, 4].

These two types of responses to CC must be combined and considered as complementary to achieve positive results. In other words, adaptation measures alone may prove inefficient to deal with the impacts of global warming [1]. The capacity to adapt to CC and its impacts is influenced by a complex set of factors, including socioeconomic situation and policy choices. This shows that adaptation is a dynamic process [1], requiring continuous efforts.

Mitigating measures

Mitigating measures target at the reduction of GHG emissions and, therefore, are mainly related to energy production and consumption. Increasing the efficiency of fuels, producing energy efficient machines, and replacing the old ones (recycling will boost this plan) are steps towards reducing the emission of these pollutants [1]. As mentioned before, both environment and health benefit from this reduction [e.g.,, 4]. An effective GHG reduction policy will contribute to environmental quality and improve health.

Mitigation includes measures promoting the transition to sustainable energy, i.e. the use of solar, wind and water power, to CO_2 neutral buildings, cities and regions, and to a more efficient mobility. Moreover, agriculture should be less globalized and demand less inputs of materials, products and energy. Examples of mitigating measures include: the use of solar photovoltaic systems, the use of more efficient vehicles and lighting, recycling processes and reforestation (forests are a major carbon sink) [1, 4, 83].

Also lifestyle and behavior can enhance mitigation efforts. For instance, more bicycling and walking, the adoption of personal energy-saving efforts, the reduction of household waste and the avoidance of superfluous consumption are environmentally friendly options that people can adopt to contribute to the mitigation processes [1].

Adaptation measures

Adaptation measures target to increase resilience and reduce vulnerability to CC [e.g., 3, 4]. Adaptation refers to negative impacts that are currently ongoing and to their negative impacts that are expected during the following decades [1, 3]. Adaptation can be applied in key sectors including energy use and management, water use, distribution and management, agriculture, infrastructure and settlements, human health, tourism and transport [1, 78]. Adaptation measures are either technical or managerial and often require policy initiatives.

For instance, to cope with sea level rise or with flooding, protecting the existing natural buffers and barriers (e.g., wetlands), but also building dams and “floating” buildings have preventive potential and increase resilience. Dealing with water shortage and coping with the negative impacts of a dryer climate uses the following adaptations: the piping systems transferring drinking water to areas facing water shortage, water re-use, new varieties of drought-resistant crops, and improving irrigation. Adaptation to (main) wildfires necessitates more prevention, water sources and fire-fighters. Other adaptation strategies include crop relocation, changes in pesticide use, improved road planning and design, combining multiple sources of energy, increased reliability of forecasts of extreme weather events, and increased public awareness, education and training of the emergency staff, among others in local governments [1, 3, 4, 75, 78, 84]. Family planning is another adaptation measure which keeps a population within sustainable ranges and prevents uncontrolled population growth which can intensify the impacts of CC [4].

Simple adaptation measures anyone can apply exist and include: the use of screens and nets preventing mosquito bites [3]. More complex adaptation strategies should be applied with care and attention should be paid avoiding negative feedback. For example, if local governments use air-conditioning in public spaces, the energy source should be carefully selected, avoiding an increase in GHG emissions and the enhancement of the urban heat island effect [3].

Both direct and indirect health benefits are associated with adaptation to CC. For instance, adaptation in the health care sector benefits health directly. This can be realized e.g., by funding health programs, enhancing health infrastructure resilience, improving surveillance of climate sensitive diseases and by organizing appropriate education and training programs for health professionals to transfer both explicit and tacit knowledge on climate change, its impacts and responses [1, 78, 85].

Action on climate change affects health in different ways. For instance walking and bicycling also reduce the amounts of pollutants emitted by traffic [1, 15]. The effects are particularly obvious in pedestrianized urban centers. Making cities and mobility more sustainable, not only results in less exposure to air pollutants, but also improves the physical condition of people. Green areas improve the health of the people living nearby, e.g., through their cooling impact on the urban heat island effect [86], less visits to doctors and hospital days, lower consumption of medical drugs and less consultations on psychological indications [see 87, 88].

Many adaptation (or mitigation or both adaptation and mitigation) strategies are directed towards the reduction of the existing or the expected health risk factors or towards improving health. For instance, adequate decisions on energy, water and material efficiency of buildings contribute to improved indoor air quality and to more sustainable lifestyles, which are less threatening for health.

Conclusions

Current climate change evolves towards a major health risk, causing direct and indirect effects and offers a real policy and management challenge to. Climate outcomes and their health impacts can only be predicted within wide margins of uncertainty. However, uncertainty should not be used advocating inertia in the adoption of mitigation and adaptation measures. A precautionary approach in the management responses allows reducing global warming related health risks.

Vulnerability varies among social classes, poor and wealthy nations, and over time. The severity of the CC related health impacts reveals the urgent need to act. Adequate planning incorporates environmental health. The measures proposed benefit both the natural environment and human health.

Unfortunately, the CC / environmental / health triple win situations are rare. Of core importance are comprehensive local, regional and national climate plans addressing CC effects in an integrated and societally supported way. Monitoring should make sure the plans reach their targets. Practical instruments as group purchases of green energy, eco-doctors, subventions, training, education and awareness significantly contribute to these plans and to transitions at the local level.

References

[1] IPCC: Climate Change 2007: Synthesis Report. An assessment of the Intergovernmental Panel on Climate Change. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf (2008). Accessed 05 January 2013

[2] M.J. Salinger, Climate Variability and Change: Past, Present and Future – An Overview, Climatic Change, 70 (2005) 9-29.

[3] U. Confalonieri, B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revich, A. Woodward, In: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge 2007, pp. 391-431.

[4] A. Costello, M. Abbas, A. Allen, S. Ball, S. Bell, R. Bellamy, S. Friel, N. Groce, A. Johnson, M. Kett, M. Lee, C. Levy, M. Maslin, D. McCoy, B. McGuire, H. Montgomery, D. Napier, C. Pagel, J. Patel, J.A.P. de Oliveira, N. Redclift, H. Rees, D. Rogger, J. Scott, J. Stephenson, J. Twigg, J. Wolff, C. Patterson, Managing the health effects of climate change, Lancet, 373 (2009) 1693-1733.

[5] A.J. McMichael, A. Haines, Global climate change: the potential effects on health, BMJ, 315 (1997) 805-809.

[6] Hippocrates: On Airs, Waters and Places (400 B.C.E., translated by F. Adams). http://classics.mit.edu/Hippocrates/airwatpl.html. Accessed 05 January 2014

[7] V. Ramanathan, Y. Feng, Air pollution, greenhouse gases and climate change: Global and regional perspectives, Atmos. Environ., 43 (2009) 37-50.

[8] T.S. Ledley, E.T. Sundquist, S.E. Schwartz, D.K. Hall, J.D. Fellows. T.L. Killeen, Climate Change and Greenhouse gases, Eos, 80 (1999) 453-458.

[9] L. Hens, In: E.K. Boon, Area Studies – Regional Sustainable Development: Africa – Vol. II, Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford 2009, pp. 308-328.

[10] M.L. Dolfman, S.F. Wasser, B. Bergman, The effects of Hurricane Katrina on the New Orleans economy, Mon. Labor. Rev., 130 (2007) 3-18.

[11] J. Barnett, W.N. Adger, Climate change, human security and violent conflict, Pol. Geogr., 26 (2007) 639-655.

[12] C. Rosenzweig, G. Casassa, D.J. Karoly, A. Imeson, C. Liu, A. Menzel, S. Rawlins, T.L. Root, B. Seguin, P. Tryjanowski, In: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge 2007, pp. 79-131.

[13] G.-R. Walther, E. Post, P. Convey, A. Menzel, C. Parmesan, T.J.C. Beebee, J.-M. Fromentin, O. Hoegh-Guldberg, Franz Bairlein, Ecological responses to recent climate change, Nature, 406 (2002) 389-395.

[14] S. Yannas, Toward more sustainable cities, Sol. Energy, 70 (2001) 281-294.

[15] M.M. Betsill, Mitigating Climate Change in US Cities: opportunities and obstacles, Local Environ., 6 (2001) 393-406.

[16] H.G. Bohle, T.E. Downing, M.J. Watts, Climate change and social vulnerability: Toward a sociology and geography of food insecurity, Global Environ. Change, 4 (1994) 37-48.

[17] B. Smit, J. Wandel, Adaptation, adaptive capacity and vulnerability, Global Environ. Change, 16 (2006) 282-292.

[18] M.M.Q. Mirza, Climate change and extreme weather events: can developing countries adapt?, Clim. Policy, 3 (2003) 233-248.

[19] W.N. Adger, S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D.R. Nelson, L.O. Naess, J. Wolf, A. Wreford, Are there social limits to adaptation to climate change?, Climatic Change, 93 (2009) 335-354.

[20] M.R. Allen, P.A. Stott, J.F.B. Mitchell, R. Schnur, T.L. Delworth, Quantifying the uncertainty in forecasts of anthropogenic climate change, Nature, 407 (2000) 617-620.

[21] IPCC, In: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor, H.L. Miller, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY 2007, pp. 1-18.

[22] World Meteorological Organization, WMO statement on the status of the global climate in 2012, World Meteorological Organization, Geneva, 2013.

[23] IPCC, In: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge 2007, pp. 7-22.

[24] C.D. Thomas, A. Cameron, R.E. Green, M. Bakkenes, L. J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M.F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Phillips, S.E. Williams, Extinction risk from climate change, Nature, 427 (2004) 145-148.

[25] O. Hoegh-Guldberg, Climate change, coral bleaching and the future of the world's coral reefs, Mar. Freshwater Res., 50 (1999) 839-866.

[26] R.S. Kovats, A. Haines, R. Stanwell-Smith, P. Martens, B. Menne, R. Berollini, Climate change and human health in Europe, BMJ, 318 (1999) 1682-1685.

[27] J.A. Patz, D. Campbell-Lendrum, T. Holloway, J.A. Foley, Impact of regional climate change on human health, Nature, 438 (2005) 310-317.

[28] S. Rodríguez, A. Alastuey, S. Alonso-Pérez, X. Querol, E. Cuevas, J. Abreu-Afonso, M. Viana, N. Pérez, M. Pandolfi, J. de la Rosa, Transport of desert dust mixed with North African industrial pollutants in the subtropical Saharan Air Layer, Atmos. Chem. Phys, 11 (2011) 6663-6685.

[29] D.W. Griffin, C.A. Kellogg, Dust Storms and Their Impact on Ocean and Human Health: Dust in Earth's Atmosphere, EcoHealth, 1 (2004) 284-295.

[30] E.A. Shinn, D.W. Griffin, D.B. Seba, Atmospheric Transport of Mold Spores in Clouds of Desert Dust, Arch. Environ. Health, 58 (2003) 498-504.

[31] B.L. Diffey, Ultraviolet radiation and human health, Clin. Dermatol. 16 (1998) 83-89.

[32] M. Norval, Immunosuppression induced by ultraviolet radiation: relevance to public health, B. World Health Organ., 80 (2002) 906-907.

[33] D.J. Jacob, D.A., Winner, Effect of climate change on air quality, Atmos. Environ., 43 (2009) 51-63.

[34] K.L. Ebi, G. McGregor, Climate Change, Tropospheric Ozone and Particulate Matter, and Health Impacts, Environ. Health. Perspect., 116 (2008) 1449-1455.

[35] J.T. Spickett, H.L. Brown, K. Rumchev, Climate Change and Air Quality: The Potential Impact on Health, Asia Pac. J. Public Health, 23 (2011) 37S-45S.

[36] J. Anderson, C. Bausch: Climate Change and Natural Disasters: Scientific evidence of a possible relation between recent natural disasters and climate change. http://www.europarl.europa.eu/RegData/etudes/note/join/2006/373583/IPOL-ENVI_NT(2006)373583_EN.pdf (2006). Accessed 05 January 2014

[37] T.J. Doherty, S. Clayton, The Psychological Impacts of Global Climate Change, Am. Psychol., 66 (2011) 265-276.

[38] J. Shukla, Extreme Weather Events and Mental Health: Tackling the Psychosocial Challenge, ISRN Public Health, 2013 (2013), 7 pages.

[39] Yoganathan D., W.N., Rom, Medical Aspects of Global Warming, Am. J. Ind. Med., 40 (2001) 199-210.

[40] H. Kan, R. Chen, S. Tong, Ambient air pollution, climate change, and population health in China, Environ. Int. 42 (2012) 10-19.

[41] G. Luber, M. McGeehin, Climate Change and Extreme Heat Events, Am. J. Prev. Med., 35 (2008) 429-435.

[42] J.A. Omumbo, S.I. Hay, S.J. Goetz, R.W. Snow, D.J. Rogers, Updating Historical Maps of Malaria Transmission Intensity in East Africa Using Remote Sensing, Photogramm. Eng. Rem. S., 68 (2002) 161-166.

[43] R.C. Dhiman, S. Pahwa, G.P.S. Dhillon, A.P. Dash, Climate change and threat of vector-borne diseases in India: are we prepared?, Parasitol. Res., 106 (2010) 763-773.

[44] S.W. Lindsay, W.J.M. Martens, Malaria in the African highlands: past, present and future, B. World Health Organ., 76 (1998) 33-45.

[45] A. Fouillet, G. Rey, F. Laurent, G. Pavillon, S. Bellec, C. Guihenneuc-Jouyaux, J. Clavel, E. Jougla, D. Hémon, Excess mortality related to the August 2003 heat wave in France, Int. Arch. Occup. Environ. Health, 80 (2006) 16-24.

[46] J.-M. Robine, S. L. K. Cheung, S. Le Roy, H. van Oyen, C. Griffiths, J.-P. Michel, F. R. Herrmann. Death toll exceeded 70,000 in Europe during the summer of 2003, C. R. Biol, 331 (2008) 171-178

[47] K. Katsouyanni, D. Trichopoulos, X. Zavitsanos, G. Touloumi, The 1987 Athens heatwave, Lancet, 332 (1988) 573.

[48] A. Flynn, C. McGreevy, E.C. Mulkerrin, Why do older patients die in a heatwave?, Q. J. Med., 98 (2005) 227-229.

[49] M. Ahern, R.S. Kovats, P. Wilkinson, R. Few, F. Matthies, Global Health Impacts of Floods: Epidemiologic Evidence, Epidemiol. Rev., 27 (2005) 36-46.

[50] E. Euripidou, V. Murray, Public health impacts of floods and chemical contamination, J. Public Health, 26 (2004) 376-383.

[51] M. Brandt, C. Brown, J. Burkhart, N. Burton, J. Cox-Ganser, S. Damon, H. Falk, S. Fridkin, P. Garbe, M. McGeehin, J. Morgan, E. Page, C. Rao, S. Redd, T. Sinks, D. Trout, K. Wallingford, D. Warnock, D. Weissman, Mold Prevention Strategies and Possible Health Effects in the Aftermath of Hurricanes and Major Floods, MMWR Recomm. Rep., 55 (2006) 1-27.

[52] M.P. Fabian, S.L. Miller, T. Reponen, M.T. Hernandez, Ambient bioaerosol indices for indoor air quality assessments of flood reclamation, J. Aerosol Sci., 36 (2005) 763-783.

[53] O. Koskinen, T. Husman, A. Hyvärinen, T. Reponen, A. Nevalainen, Respiratory Symptoms and Infections among Children in a Day-Care Center with Mold Problems, Indoor Air, 5 (1995) 3-9.

[54] A.K. Githeko, S.W. Lindsay, U.E. Confalonieri, J.A. Patz, Climate change and vector-borne diseases: a regional analysis, B. World Health Organ., 78 (2000) 1136-1147.

[55] J.M. Shultz, J. Russell, Z. Espinel, Epidemiology of Tropical Cyclones: The Dynamics of Disaster, Disease, and Development, Epidemiol. Rev., 27 (2005) 21-35.

[56] K.E. Smoyer-Tomic, J.D.A. Klaver, C.L. Soskolne, D.W. Spady, Health Consequences of Drought on the Canadian Prairies, EcoHealth, 1 (2004) 144-154.

[57] G. Surber, Toxic Algae: Potential in Drought Limited Water Supplies, Publications & Information, Animal & Range Sciences, Extension Service, Montana State University. http://animalrangeextension.montana.edu/articles/NatResourc/Toxic%20Algae.pdf (2001). Accessed 06 January 2014

[58] United Nations Department of Economic and Social Affairs, Population Division: Population Facts: Accelerating achievement of the MDGs by lowering fertility: Overcoming the challenges of high population growth in the least developed countries. http://www.un.org/en/development/desa/population/publications/pdf/popfacts/popfacts_2010-5.pdf (2010). Accessed 06 January 2014

[59] B. Bates, Z.W. Kundzewicz, S. Wu, J. Palutikof, Climate Change and Water, Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 2008.

[60] G. Várallyay, Potential Impacts of Climate Change on Agro-ecosystems, Agric. Conspec. Sci., 72 (2007) 1-8.

[61] J. Schmidhuber, F.N. Tubiello, Global food security under climate change, PNAS, 104 (2007) 19703-19708.

[62] C. Benson, E. Clay, Understanding the Economic and Financial Impacts of Natural Disasters, The International Bank for Reconstruction and Development / The World Bank, Washington, 2004.

[63] R.S.J. Tol, Estimates of the Damage Costs of Climate Change Part 1: Benchmark Estimates, Environ. Resour. Econ., 21 (2002) 47-73.

[64] W.D. Solecki, C. Rosenzweig, L. Parshall, G. Pope, M. Clark, J. Cox, M. Wiencke, Mitigation of the heat island effect in urban New Jersey, Environ. Hazards, 6 (2005) 39-49.

[65] M.A. Hanjra, M.E. Qureshi, Global water crisis and future food security in an era of climate change, Food Policy, 35 (2010) 365-377.

[66] C.R. Carere, R. Sparling, N. Cicek, D.B. Levin, Third Generation Biofuels via Direct Cellulose Fermentation, Int. J. Mol. Sci., 9 (2008) 1342-1360.

[67] M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, C.E.Hanson, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge 2007.

[68] J. Ribot, In: R. Mearns, A. Norton, Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World, The International Bank for Reconstruction and Development / The World Bank, Washington 2010, pp. 47-74.

[69] N. Brooks, W.N. Adger, P.M. Kelly, The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation, Global Environ. Change, 15 (2005) 151-163.

[70] R. Mearns, A. Norton, In: R. Mearns, A. Norton, Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World, The International Bank for Reconstruction and Development / The World Bank, Washington 2010, pp. 1-44.

[71] S.D. Donner, W.J. Skirving, C.M. Little, M. Oppenheimer, O. Hoegh-Guldberg, Global assessment of coral bleaching and required rates of adaptation under climate change, Global Change Biol., 11 (2005) 2251-2265.

[72] R.J. Nicholls, Coastal Megacities and Climate Change, GeoJournal, 37 (1995) 369-379.

[73] UN-Habitat: What are slums and why do they exist? http://www.unhabitat.org/downloads/docs/4625_51419_gc%2021%20what%20are%20slums.pdf. Accessed 05 January 2014

[74] E. Marino, J. Ribot, Special Issue Introduction: Adding insult to injury: Climate change and the inequities of climate intervention, Global Environ. Change, 22 (2012) 323-328.

[75] B. Smit, O. Pilifosova, In: J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken, K.S. White, Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge 2001, pp. 877-912.

[76] D.A. Stainforth, T. Aina, C. Christensen, M. Collins, N. Faull, D.J. Frame, J.A. Kettleborough, S. Knight, A. Martin, J.M. Murphy, C. Piani, D. Sexton, L.A. Smith, R. A. Spicer, A.J. Thorpe, M.R. Allen, Uncertainty in predictions of the climate response to rising levels of greenhouse gases, Nature, 433 (2005) 403-406.

[77] J.F. Clarke, W. Bach, Comparison of the Comfort Conditions in Different Urban and Suburban Microenvironments, Int. J. Biometeor., 15 (1971) 41-54.

[78] S. Hallegatte, Strategies to adapt to an uncertain climate change, Global Environ. Change, 19 (2009) 240-247.

[79] S. Dessai, M. Hulme, R. Lempert, R. Pielke Jr., In: W.N. Adger, I. Lorenzoni, K.L. O'Brien, Adapting to Climate Change: Thresholds, Values, Governance, Cambridge University Press 2009, pp. 64-78.

[80] R.S. Kovats, D. Campbell-Lendrum, F. Matthies, Climate Change and Human Health: Estimating Avoidable Deaths and Disease, Risk Anal., 25 (2005) 1409-1418.

[81] United Nations: United Nations Framework Convention on Climate Change, http://unfccc.int/resource/docs/convkp/conveng.pdf (1992). Accessed 04 January 2014

[82] I.M. Goklany: Applying the Precautionary Principle to Global Warming. Center for the Study of American Business. http://wc.wustl.edu/files/wc/imce/applying_the_precautionary_tale.pdf (2000). Accessed 05 January 2014

[83] A. Revi, Climate change risk: an adaptation and mitigation agenda for Indian cities, Environ. Urban., 20 (2008) 207-229.

[84] I. Douglas, K. Alam, M. Maghenda, Y. Mcdonnell, L. Mclean, J. Campbell, Unjust waters: climate change, flooding and the urban poor in Africa, Environ. Urban., 20 (2008) 187-205.

[85] World Health Organization, Protecting HEALTH from climate change: messages to health professionals: Climate change will be the defining issue for health systems in the 21st century. Health professionals have the knowledge,

cultural authority and responsibility to protect health from climate change. http://www.who.int/globalchange/publications/factsheets/WHD2008_health_prof_2.pdf (2008). Accessed 05 January 2014

[86] N.H. Wong, C. Yu, Study of green areas and urban heat island in a tropical city, Habitat Int., 29 (2005) 547-558.

[87] A.Almusaed, Biophilic and Biocliamtic Architecture: Analytical Therapy for the Next Generation of Passive Sustainable Architecture, Springer-Verlag, London, 2011.

[88] Forest Research, Benefits of green infrastructure. Report by Forest Research, Forest Research, Farnham, 2010