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Climate change and human health: an environmental perspective

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ABSTRACT: Projected impacts of climate change on human health are immense, and mitigating these impacts will require a large-scale concerted effort involving various global organisations. A recent report by University College London (Costello et al. 2009; Lancet 373: 1693–1733) has produced a comprehensive list of climate change impacts on human health. This article highlights some of the adverse impacts of climate change that received little or no attention in Costello et al. (2009).

KEY WORDS: Climate change · Human health · Pathogens · Chemical contaminants · Environmental responses · Extreme weather events

1. Introduction

Impacts of climate change on human health are immense, and there is an urgent need to address this issue by researchers, governmental, non-governmental and inter-governmental agencies. In this context, the recent report by Costello et al. (2009) is timely, detailed and scientifically stimulating. However, the effects of some major environmental variables and their interactions were overlooked. In the present paper, I highlight some environmental factors that received little or no attention from Costello et al. (2009) but which may have adverse impacts on human health. Environmental quality is intrinsically linked to human health, and therefore, responses of the natural environment to climate change will also have indirect but major impacts on human health.

It is predicted that climate change will substantially increase the intensity, frequency and duration of extreme weather events such as heavy rainfall, flooding, storms and droughts (Easterling et al. 2000). Such changes in extreme weather will not only impact directly on human health as listed in Costello et al. (2009) but also indirectly through the influence of extreme weather on the movement of biological (including pathogens) and chemical (including pesticides) contaminants by enhancing the rate and speed of their transport in water streams resulting from extreme weather events. Past research has already demonstrated that high precipitation and run-off resulted in elevated counts of faecal bacteria and infectious viruses in local coastal water (Patz et al. 2000). Increased rainfall and high temperature can substantially increase the risk of vector-borne infection. Recent work has highlighted the link between the risk of malaria and climatic conditions (Paaijmans et al. 2009). Similarly, rodent-borne leptospirosis was linked directly to heavy rainfall and flooding (Trevejo et al. 1998). Several parameters will also have interactive effects. For example, increasing temperatures will stimulate growth and survival of pathogens and vectors in some regions, while heavy rainfall will lead to increases in the frequency of human contact and thus frequency of epidemics.

Similarly, transport and risk of chemical exposure will increase substantially due to heavy rainfall. Additionally, some global parameters (e.g. temperature) will have strong effects on the environmental fate and behaviour of chemical contaminants by altering physical, chemical and biological variants of partitioning between the atmosphere, water, soil and biota (Noyes et al. 2009). Just one group of pesticides (organophosphorus compounds) is responsible for 3 million poisonings

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world-wide (Eddleston et al. 2007, Singh 2009). Coupled with frequent usages, more rapid movement due to heavy rains may substantially increase low-level organophosphorus poisoning, which has long-term effects on the nervous system (Ragnarsdottir 2000). Additionally, melting sea ice and glaciers, which have acted as long-term sinks for several toxicants, may accelerate exchange of contaminants between air and water. For example, it is estimated that reduced Artic sea ice cover could result in a proportionate doubling of polychlorinated biphenyl (a carcinogenic compound) air to sea exchange (Macdonald et al. 2005). There is already evidence of increased exposure to toxicants (herbicides) due to heavy rainfall (Vu et al. 2006) and this was highlighted following Hurricane Katrina in New Orleans (in 2005), where soil and sediment concentrations of several toxicants and pathogens were reported to exceed US Environmental Protection Agency exposure limits (Presley et al. 2006).

Global warming may facilitate invasion of various landscapes with alien species. There are already reports of invasions of various plants and animals in temperate regions due to global warming. These new arrivals may provide reservoirs or secondary hosts for human pathogens (Van der Putten et al. 2007). For example, invasion of new areas by ectoparasitic ticks may substantially increase the incidence of Lyme disease (Ebi et al. 2006). Additionally, enhanced abundance and activity of bacterial, fungal and insect pests due to global warming may necessitate increased usage of antibiotics and pesticides for agricultural purposes (Boxall et al. 2009). This will have longer-term impacts in terms of loss of efficacy of antibiotics and pesticides due to resistance development against the active ingredient, which in turn will increase the rate of infection and mortality. However, higher temperature may also lead to increased biodegradation, transportation and volatilisation of some chemical toxicants. Coupled with drier summers, this may reduce the risk of exposure in certain parts of the world. Such beneficial effects, in some cases, may be short-lived, as drier summers could also result in soil shrinkage cracks facilitating more rapid leaching of toxicants to ground waters following intense rainfall (Boxall et al. 2009). Some of the impacts may be far worse than predicted due to synergistic and interactive actions of various global changes. For example, increased temperature and salinity may enhance the chemical toxicity by altering biotransformation processes to yield more bioactive metabolites, and heavy rainfall and flooding will increase the rate of exposure to these chemicals. High exposure to chemicals (such as organophosphorus compounds) is reported to suppress immune system functions and to disturb the thermoregulatory response of the body, which in turn will reduce the ability of humans to fight various infections (Noyes et al. 2009).

There is a concern that as a result of global warming, soil organic carbon (SOC; the largest reservoir of sequestered carbon) can be depleted due to increased microbial activities (Bellamy et al. 2005). Because of its high binding capacity for biological and chemical contaminants (Hiller et al. 2009), SOC also acts as a filter for ground and surface waters. Less SOC may therefore result in higher levels of contaminated ground and surface water. This scenario can be further complicated by soil erosion caused by low soil C in combination with extreme weather events. Loss of SOC will lead to high nutrient levels in water systems (ponds, lakes, rivers and oceans), which in turn will lead to increased growth of algae (Falkowski & Oliver 2007) with implications for the availability of safe drinking water. In addition, the growth of several toxin-producing blue-green algae (BGA) may be promoted, posing a health hazard with associated risk of fatalities worldwide. For example, it is already reported that high temperature will promote algal blooms in fresh and marine water, and there is a strong linkage between climate and the magnitude, frequency and duration of algal blooms (Moore et al. 2008). Toxic algae have both indirect and direct effects on human health. Algal toxins are bioaccumulated in feeding shellfish and pass along the food chain causing health problems or fatalities, including in humans. Along with increased algal blooms, heavy rain and flooding will increase the incidence of toxin exposure and thus illness and fatalities in human populations.

2. What are the ways forward?

In the short term, the harmful impact of global warming is unavoidable, and we therefore need to develop approaches that substantially mitigate the effects. This can be achieved by a coordinated effort involving multidisciplinary experts, multiple organisations and inter-governmental agencies such as the World Health Organisation. Effective surveillance systems for monitoring transport and persistence of pathogens and chemical contaminants in natural environments are needed. New biosensors/bio-indicators or rapid methodologies for real-time detection will be essential to minimise harmful effects. In the medium term, we have to ensure that we do not lose existing forest cover and that we maintain natural environments such as peatland and highly organic soils. Deforestation is considered to be the single greatest threat to the carbon sink function, and it is estimated that in the last 200 yr, deforestation alone has accounted for 30% of anthropogenic release of atmospheric CO_2 (Reay et al. 2007). Maintenance (and expansion, if possible) of land under forest cover is essential to avoid further worsening of global warming and its impacts. This must be further assisted by research and development in farming technologies that have a low carbon footprint. Currently, there is no long-term alternative to this approach. To achieve this goal, we need to effect a behavioural change by combining economic penalties and increased social awareness. This may lead to adoption of energy saving, development and adoption of energy efficient technologies by farmers and corporations. The natural environment offers one of the best options for the carbon sink. For example, soils contain about 1500 Pg (10^{15} g) of organic carbon worldwide, which is about twice the amount of carbon in the atmosphere and 3 times the amount in vegetation (Smith 2004). However, this sequestered carbon is under threat from increased microbial decomposition due to higher temperature and heavy rainfall predicted by various climate models; therefore, an effective approach to limit loss of SOC is essential (Bellamy et al. 2005). Importantly, it is possible to manipulate (by land-use change and management practices) our terrestrial system in such a way to further sequester up to 100×10^{12} g C globally (Houghton 2007), which would offset about 60 yr worth of CO_2 emissions at the current rate from the transport sector (Agrawal 2007). To achieve increased C sequestration in soils, there is a need to develop a land-use policy that promotes increased net primary productivity and C storage and reduces greenhouse gas flux (Dawson & Smith 2007). For example, afforestation of less productive, degraded agricultural fields and pastures can substantially increase C storage in soils. Further research is needed to identify how this can be achieved without compromising food security and social prosperity.

3. Concluding remarks

The impact of various global changes on human health will be interactive in nature, and effects may be far worse than predicted due to synergistic actions. Therefore, understanding the effects of multiple stressors on the responses of various interacting variables is essential to develop an effective strategy for mitigation of health impacts of climate change. Transmission of vector-borne diseases is a good example to illustrate how several concurrent but interacting global changes can simultaneously affect human health. For example, a leptospirosis epidemic in Nicaragua was reported to be caused jointly by climatic conditions, forest clearance, land use and management, loss of biodiversity (natural predator of vector), water surface configuration and density of human populations (World Health Organisation 2003). Therefore, to predict and minimise climate change impacts on human health, we need an effective and integrated mechanism to monitor pathogens and chemical contaminants not only in human populations but also in the natural environment. We also need to have well defined goals for the short, medium and long term in order to effectively manage harmful impacts of climate change on human health. In this respect, using the so called 'disease triangle concept', an approach that utilises integration of 3 interconnected aspects, i.e. host, pathogens and environment (Scholthof 2007), is suggested. This holistic approach combines the data from climate change, habitats, migration, socioeconomics and related politics as a factor to contribute to disease and epidemiology. It is suggested that the disease triangle can help in evaluating and identifying triggers for the manifestation of disease (Scholthof 2007). Based on this understanding, an early warning system can be developed to control the spread of diseases. The potential impact of climate change on human health is huge, but it is also related to effects on our environment. Therefore, for quantitative information on climate change impact and efforts to minimise those impacts on human health, concerted multidisciplinary approaches are needed. However, any such approach will only be effective if it also includes responses of the natural environment to climate change as an integral part in all evaluations and decision-making processes.

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