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Health consequences of climate change : A consensus scientific warning

by

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All living organisms are consubstantial with their habitat. They are, in terms of thermodynamics and cybernetics, open systems: without perfect adequation with their cosmic environment, they cannot survive and develop. Applied to man, this fundamental biological law implies that we are merely what our environment allows us to be and our health results from this. Under these conditions, the importance of climate change and its anthropic origin, as it is confirmed by IPCC's , *Intergovernmental Panel on Climate Change,* fourth report, poses the vital question of consequences on health, and more specifically, medical consequences we will have to face in this century and the means we will need to implement to confront them. Global warming and its health effects have by now become a reality. In 2002, WHO believed that 150,000 people had died due to climate change over the last 30 years. We would be better off preventing health damage rather than suffering. Though facing many uncertainties, this report has been commissioned by ONERC, the French National Observatory on Global Warming. Its aim is to sum up some available medical and scientific data in order to offer political decision-makers sensible guidelines based on practical targets, intended to circumscribe and soften, if not prevent, health effects caused by climate change.

The present document is adapted from the ARTAC report that was addressed to the Primer Minister and the Parliament of France in March 2007 by ONERC[1]. This document is also derived from the Paris Appeal[2]. It can only be considered as a first step, because expertise in the field of environmental health and medicine is complex and therefore requires to be interdisciplinary.

Methodological aspects

There are numerous difficulties. Although direct health effects linked to the occurrence of severe conditions (thermal stress, storms, cyclones, hurricanes, droughts, floods, etc) are relatively easy to identify and to relate to their causes, the same does not apply to indirect health effects, which are far less visible and more pernicious, and thus difficult to prevent and halt. The fact that our health is consubstantial with various natural ecosystems that are not well known, and that climate change can modify each biotic or non-biotic element within these eco-systems must prompt us to be extremely careful when interpreting facts and carrying out forecasts. In this case, two complementary methodological approaches stand face to face that should both be considered: that of *health ecology* , which consists in analyzing environmental degradation and attempts to assess consequences on health, and that of *environmental health*, which, based on illnesses, tries to determine causes by studying environmental risk factors[3]. In both cases, the greatest issue is to establish scientifically a causal link. To this end, epidemiological studies are indeed inadequate, as they highlight an associated link at best (all emergence correlations do not necessarily rely on causality). Thus, scientists need to interpret epidemiological data in close association with toxicological *in vitro*

[1] Rapport de l'ONERC au Premier Ministre et au Parlement. Changements climatiques et risques sanitaires en France : surveillance et systèmes d'alerte.
[2] International Declaration on diseases due to chemical pollution presented in UNESCO by the ARTAC and signed by hundreds of scientists, including the three French Medicine Nobel Prices Prs Jacob, Dausset and Montagnier.
[3] D. Belpomme : Avant qu'il ne soit trop tard (Before it's too late), Ed. Fayard, Paris, 2007

and *in vivo* studies, which may establish in the laboratory a causal link, and with biological studies which may highlight results of both epidemiological and toxicological studies. In addition biological studies in the general sense of the word, encompass not only ecological, but also ethological and more particularly entomological studies, which are likely to provide coherent eco-systemic models. We have however to keep in mind that any modeling is by nature a simplistic viewpoint and thus a source of errors. To these difficulties, one should add the fact that, in terms of health and medical forecast, we reason on what we observe today, *i.e.* on infectious agents and ecosystems we now know, but we do not know what will be new emerging infectious agents and transmission vectors, and therefore what diseases scientists and medical practitioners will need to fight against : who could have predicted the onset of AIDS, SRAS, the variants of Creutzfeld-Jakob disease and of scores of other infectious diseases that have emerged over the last 30 years ? Nevertheless, in spite of these difficulties, several lines of force can be considered.

Direct health effects

Health effects directly linked to global warming are certainly the most serious, as they "directly" threaten the human populations concerned. The physiological adaptation of any complex living organism, including man, is possible only in certain narrow limits. Beyond or below these limits, life becomes impossible. Without any effective protection, extreme conditions can therefore not only lead to vital toxicity and consequently to death for man by hypo- or hyperthermia, dehydration, famine, shock or trauma, but also to the suppression of the flora and fauna with which man is consubstantial.

Moreover, anthropic causes of degradation of the biosphere form a whole. To the effects of global warming itself, we must add specific biological and health repercussions of solar ultraviolet rays increase, related to the destruction of the *stratospheric* ozone layer. Moreover, we should add the toxic effects of physico-chemical pollution caused by other human activities. This is the case for the increase in *tropospheric* ozone due to urban traffic, which itself is heightened by global warming. In actual fact, the precise causes of the death of living organisms and of the degradation of ecosystems are thus numerous and often difficult to anticipate and detect. Yet, however unknown causes may be, it is clear that, according to Darwinian selection, the most fragile organisms and ecosystems are and will be doomed. And this goes for man and the human race, as well as for any complex organism. From a health and social viewpoint, the poorest people, the most fragile people, living in the most inhospitable areas on Earth, those that are the most exposed to global warming, will undoubtedly be the first victims.

The main issue here is thus to delay as much as possible the anthropic increase in mean temperature on Earth by limiting the worsening of the greenhouse effect, in order to allow ecosystems to survive as long as possible and men, including the poorest people, to protect themselves.

Indirect health effects

Taking into account the previous methodological limits, three types of health effects directly or indirectly linked to global warming can be identified :

1. diseases linked to increased scarcity and pollution of water,

2. diseases linked to air pollution,
3. emergence or re-emergence of eco-systemic diseases implying or not vector transmission.

1. *Diseases linked to increased scarcity and pollution of water*

Water shortage caused by droughts and desertification of the most exposed areas, in association with a lack of hygiene is bacterial infection. The reappearance of cholera, an increased occurrence of salmonellosis, including typhoid fever, is a possibility which cannot be set aside. Potential contamination of the food chain is a priority here. Although the quality of the health systems in developed countries can limit this risk, this will not be the case in developing countries. In any case additional precautions will need to be taken.

2. Diseases linked to air pollution

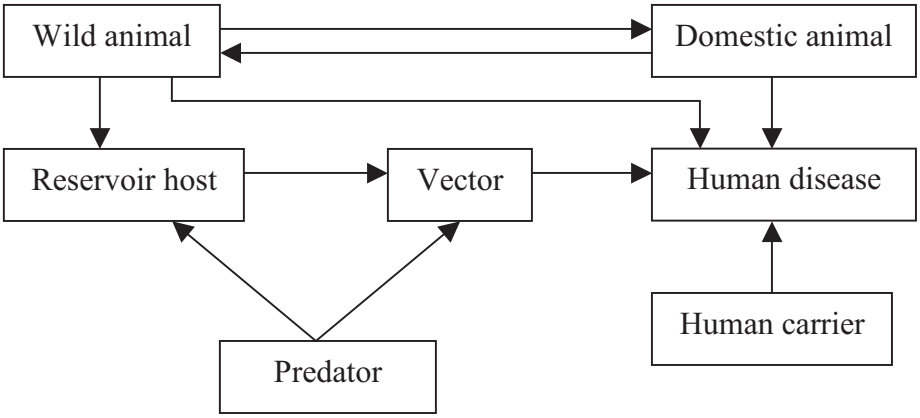
The surge of chemical pollution of inside air (homes, public buildings and workplaces) as well as outside air (especially in towns and cities) under the effect of global warming, and consequently an increase in related acute or chronic toxic effects, must be taken into consideration. However, there is no doubt that respiratory allergies should be a priority in this context. This is already what can be seen today in Europe, where, according to the European Commission, one child out of seven suffers from asthma. Allergies are very frequent. This is particularly the case in France where approximately 20% of citizens, i.e. about 10 to 12 million of them, present different forms of allergy. To explain the incidence increase in these phenomena, two different scientific theories have been put forth, although one does not exclude the other: (1) change in populations' "atopic" conditions, which makes them more susceptible to allergies[4], and (2) environmental causes, including the increase in atmospheric fine and ultrafine particles (which carry allergens) and the appearance of airway hypersensitivity pollinosis. Regarding the latter theory, as highlighted by J.C. Cohen and J.P. Besancenot, there are two possible scientific explanations, which do not exclude one another : the first hypothesis is that due to temperature-rise (milder winters, warmer springs) the increase in the number of pollen grains discharged in the atmosphere might account for an early and prolonged pollination due to temperature rise (milder winters, warmer springs) while the second hypothesis is that more important pollination might be the result of the excess of carbon dioxide in the atmosphere (under the effect of CO2, plants discharge more pollen); meaning that the increase in the allergenic effect of pollen grains, could be caused by the effect of associated atmospheric chemical pollution, chemical pollutants being able to promote the release of allergenic proteins from pollen grains.

Whatever the hypothesis considered, it clearly appears that atopic changes alone cannot explain the drastic incidence increase in respiratory allergies caused by natural chemicals as it is presently observed in Europe and other industrialized countries worldwide and consequently that environmental causes have emerged, among which global warming most certainly takes up an important part. This is probably why WHO anticipates that 50% of the global population could be affected by allergies at the end of this century!

3. Eco-systemic diseases

[4] *Atopy* is the physical or hereditary ability to present allergies. It may be related to reactive immune lymphoid cells and to abnormal production of particular immunoglobulins, IgE antibodies, previously called "reagins".

This is where lies the most unknown factor owing to the great complexity of eco-systems involved. As shown in the chart below, domestic or wild animals, reservoir hosts, vectors, predators, sick people or healthy germ carriers belong to as many eco-systems. To characterize eco-systems, to study how they work and determine their different links, to understand how their degradation may be the cause of infectious diseases is a difficult task that too few researchers have undertaken today.



However, in an attempt at forecasting the occurrence of climate change-related ecosystemic diseases, there are presently three main lines to follow:

i. Most human infectious diseases, before being transmitted from man to man, come from zoonotic diseases. Zoonotic diseases should therefore be taken into consideration first and foremost. They encompass the ones known for years as well as those recently emerging, and among them, more specifically those able to develop into extensive epizootic diseases.

ii. Among eco-systems, global warming impacts on transmission vectors as a priority (refer to chart above). This means that fighting against vector-borne infectious diseases should be a priority, even if diseases that are directly transmitted from animal to man (through an inert medium) or even from man to man should not be ignored.

iii. To the loss in biodiversity induced by global warming, two other factors should be added accounting for how infectious diseases are triggered: (1) the degradation of eco-systems resulting from human activities (chemical pollution, destruction of animal habitats) and (2) the induction of immuno-deficiency among exposed animal and human populations. And yet, here, domestic animals are concerned due to breeding conditions (limited space, artificial food, chemical doping).

We therefore conclude that the potential congruence of these factors should be considered to interpret the virulence change in micro organisms, in particular mutations of viruses.

3.1. Vector-borne diseases

Taking into account analysis of F. Rodhain (Pasteur Institute) and because temperature rise may be accompanied by humidity conditions, four types of changes in transmission vectors (essentially arthropods) can be identified under the influence of climate change :

i. an increase in size of the population due to longer life expectancy and/or shortening of the vector's development cycle ;

ii. a niche extension consisting in an altitude and latitude movement ;

iii. an increase in virulence and thus in the contamination factor through different mechanisms, including an increase in pesticide resistance ;

and finally, iv. a potential increase in infectious resurgence and re-emergence of micro organisms owing to vertical and horizontal transmission of the infectious agent.

Moreover, we should consider as a priority vectors that are the most sensitive to cold (and which, because of global warming, are the first to proliferate), as well as vectors whose phenomena of resistance to extreme thermal conditions and to pesticides are the most obvious.

These different eco-systemic considerations and current observations regarding the emergence and re-emergence of infectious diseases should be viewed on the strict principle according to which diseases apparently related to climate change and diseases that are not should be clearly distinguished. Assessing and prioritizing spreading risks of these diseases in the world and particularly in Europe would become possible, under the guise of inventory and probability determination.

Four groups or types of diseases have been examined by the ARTAC working group on climate change[5]:

The spreading of **arbovirosis** is a priority risk. There is a new outbreak of dengue worldwide. According to WHO, 2.5 billion people are exposed to this risk in tropical or subtropical regions, in 100 countries, whereas it would seem that 100 million of them are contaminated, leading to approximately 500,000 hospitalizations each year and to 20,000 deaths, including many children. Hemorrhagic dengue, especially if it is accompanied by shock, is the most serious, resulting in death in most cases. Dengue is not present in Europe, but in the French DOM-TOM, particularly on French Island Réunion, in Martinique, Guadeloupe and French Guyana. Its vector *Aedes albopictus* is ubiquitous. Other similar vectors including *Aedes Aegypti* are possible. Some arguments show potential links with global warming. Thus, in countries concerned, epidemic upsurges occur during El Niño years. There is therefore no major reason to believe that dengue cannot be introduced in Europe, under the effect of global warming, especially as *Aedes albopictus* has already been detected in Metropolitan France.

Other arbovirosis can be associated with dengue, such as Chikungunya fever, which has recently broken out on French Island Réunion and occurred sporadically in metropolitan France, West Nile fever also present sporadically in metropolitan France and even Yellow Fever, Rift Valley Fever, Japanese B encephalitis, which, though not present in Europe, are far from having been eradicated in the world. It is clear that arbovirosis already present in metropolitan France can only spread under the effect of global warming and all the more so, if it is accompanied by auspicious humidity conditions.

Malaria is a second type of vector-borne disease that may potentially spread under the influence of global warming. We have to acknowledge first the fact that this disease has not been halted worldwide. On the contrary, it is spreading. Secondly, it was present in Europe, in

[5] In 2006, the Association for Research and Treatments against Cancer (ARTAC) coordinated three work groups, including one relating to interactions between climate changes and health. These workshops led to the Memorandum of the Paris Appeal. See www.artac.info.

particular in metropolitan France endemically (*anopheles* were present here) and its eradication is relatively recent. The potential reappearance of endemic malaria in Europe under the effect of global warming is disputed. Some experts believe that the risk is very low, and even non-existent. We believe that such a risk cannot be set aside, at least not in humid areas in Europe, owing to the development of phenomena of *anopheles* resistance to pesticides and of *plasmodium* resistance to antimalarial drugs.

Leishmaniasis constitutes a third potential risk. This disease is present in Europe, in particular in the South, and in other respects, its vectors, *phlebotominae*, is very sensitive to climatic changes. However, there are ways to fight against this problem.

Finally, the risk of development of **leptospirosis** needs to be considered. This disease is already present in several European countries. During the heat wave in 2003, it would seem that its upsurge was observed in metropolitan France at least in one department. However, the implementation of rat extermination campaigns should be effective against this disease.

3.2. Non vector-borne diseases

Even if vector-borne diseases should certainly be viewed as a priority, we cannot ignore non vector-borne diseases. The impacts of climate changes indeed concern not only changes in inert media – water, air, soil – and consequently, agriculture – and therefore food -, but also human and animal behaviors (this has been known since Montesquieu's climate theory !). In both cases, this may result in or promote the emergence of infectious diseases. However, there are so many uncertainties that it is impossible to risk the slightest forecast. Under the effects of climate change, in conditions of associated insalubrity and malnutrition, some infectious diseases, such as tuberculosis, could resurface or spread. Yet, synergetic associations between different diseases may occur. For example it is well known that certain infectious cancers, such as *Burkitt's lymphoma*, are not only related to a specific virus (here Epstein-Barr's virus), but also directly or indirectly to several co-factors related to climate (such as certain *arboviruses* and malaria for *Burkitt's lymphoma*)[6].

Diseases are multifactorial. If, among scores of risk factors, climate seems to be one of the most determining factors, anticipating health effects of any radical change, even if it is gradual, still involves a very important part of uncertainty.

Means of action

The aforementioned difficulties show how impossible it is to forecast precisely the diseases that tomorrow's medicine will need to face. However, we must act now. As regards health, the key action is *prevention*, when risk factors are known, and *precaution*, when they are not. Cutting back pollution from its source and more specifically fighting effectively against the greenhouse effect are top most priorities, as everything depends on it, including populations' health. The recent awareness of authorities in general and political authorities in particular in favor of the fight against the degradation of our environment, as shown in the *United Nations Framework Convention on Climate Change* (UNFCCC) of November 2006 in Nairobi, in IPCC's fourth report, in the *European Commission*'s Green Book on adaptation (February 2007) and more recently the Paris Conference of February 2-3, 2007, suggesting a world

[6] C A Van Den Bosch, Is endemic Burkitt's lymphoma an alliance between three infections and a tumor promoter ?, Lancet Oncol 2004,5: 738-46.

governance as regards environmental policy, might be first and positive steps. Yet, all these actions can by no means be sufficient if all the countries on earth, and first of all Europe, do not carry out in a practical way the objectives discussed.

If it does not want to be part of the victims, while keeping its universalist calling, Europe must be the spearhead in the world, as regards to environmental policy, and particularly learn for example from the experience acquired in French Island Réunion, where such a policy is being developed and could serve as an example in the fields of energy, respect of natural eco-systems and health. Avoiding health crises, while taking into account at best and in a context of emergency acquired experience, is essential. Setting up sentinel networks of early detection for diseases, while improving epidemiological monitoring nation- and world-wide, is just as essential. We also need to launch here and now targeted research on the major subjects mentioned above and therefore to develop research in health ecology and environmental medicine, not only by reinforcing clinical observations, epidemiology, biology and toxicology, but also by promoting again education and research in the field of all life sciences, especially in bacteriology, virology and entomology. Finally, we must train new researchers in these fields, educate the general public to risk management, as well as to the onset of crises, and especially convince institutional and political decision-makers that without an unrelenting determination to act practically and effectively, in actual fact, nothing can be achieved.

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