

# From past to better public health programme planning for possible future global threats: case studies applied to infection control

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**Summary.** The impact of weather change and global pollution on the development and/or the transformation of microorganisms is no longer to be demonstrated. In this respect, heavy trends can be taken into account. This general context needs the development of anticipation procedures and the knowledge of the perception of prevention by the public for short, medium and long term actions. After a short discussion on the concept of emerging issues, the authors present some past examples of public health programs. These examples (malaria, dengue, chikungunya and cholera) are used to propose optimized ways of decision/action that may help to avoid possible crisis in a rapidly changing world. Then, the different lessons learnt are, under certain limits, associated with a forecasting analysis.

*Key words:* sustainable development, emerging infectious diseases, policy making, organizational change, climate change.

**Riassunto** (*Verso un miglioramento della pianificazione dei programmi di salute pubblica in vista di possibili future minacce globali: casi-studio applicati al controllo delle infezioni*). L'impatto del cambio climatico e dell'inquinamento globale sullo sviluppo e/o la trasformazione dei microorganismi non richiede ulteriore dimostrazione. Al riguardo, andamenti tendenziali evidenti possono essere presi in considerazione. Questo contesto generale richiede che siano sviluppate procedure di anticipazione e la conoscenza della percezione da parte del pubblico delle azioni di prevenzione a breve, medio e lunghe termine. Dopo una breve discussione sul concetto di problemi emergenti, gli autori presentano degli esempi passati di programmi di salute pubblica. Questi esempi (malaria, dengue, chikungunya, cholera) sono usati per proporre modi ottimizzati di decisione/azione intesi a prevenire possibili crisi in un mondo che si modifica velocemente. Poi, le diverse lezioni apprese sono, entro certi limiti, associate con un'analisi di previsione.

*Parole chiave:* sviluppo sostenibile, patologie infettive emergenti, processi decisionali, miglioramenti organizzativi, cambiamenti climatici.

## INTRODUCTION

The definition of health, adopted by the countries member of the World Health Organization (WHO) and engraved in its Constitution in 1958 [1], is to be kept as a global target still to be reached. This "State of complete physical, mental and social well-being and not merely the absence of disease or infirmity" is, in many instances, yet to be observed in the majority of the world population, including in many developed or emerging countries. Public health programs have been successfully implemented at both national and international scale since the middle of last century, notably in the field of infectious diseases, with historical real successes. However, today it is also undeniable that the results have not always been sustained and some human pathogens are re-emerging and new or previously unidentified ones are emerging.

Past epidemics have caused the scientific community to build extensive knowledge on the patterns that preside to the evolution of many pathogens, and to warn the decision makers of possible pandemics that may induce too many deaths worldwide. The accuracy of the predictions is highly dependent on the information and data collected at the field level. The principles and methods of public health program planning are theoretically well defined and easily accessible to both, managers and the beneficiaries, as well as to decision makers.

### *Terminology issues*

A proper assessment of the problematic of emergencies and potential pandemics requires specifying what is under scrutiny, or in other words, to give the definition of both the key terms at the center of this

study: the concept of grouped cases of a disease, and the concept of emergence. Cluster, outbreak, epidemic and pandemic cover a set of assertions of the same realities, depending on the disease that is being studied. Referring to standard terminology, the following definitions are used in this paper to illustrate our matter:

- *pandemic*: the spread of a disease throughout a country, continent, or the world; a worldwide epidemic; an epidemic occurring over a wide geographic area and affecting an exceptionally high proportion;
- *epidemic*: the relatively rapid spread of a disease to large numbers of a population or to areas where it is normally prevalent: a flu epidemic is likely every year;
- *outbreak*: synonymous with epidemic; sometime preferred word as it may escape the sensationalism associated with the word epidemic; alternatively, a localized as opposed to generalized occurrence of a disease;
- *cluster*: a grouping of cases of a disease (*e.g.* a cancer cluster) is the term used to define an occurrence of a greater than expected number of cancer cases within a group of people in a geographic area over a period of time.

The above is to highlight the fact that definitions are not of a minor concern. It is sometimes difficult to make a clear distinction between the terms, which are time, space, location and disease dependent. For instance an epidemic of polio covers as few as two cases, the disease being so infrequent in the world community, while an epidemic of flu refers to a large number of cases. Thus, confusion can easily occur with deadly consequences and impact, when communication, notably in the *media*, is not well handled.

The study of emergences, applied to the area of infections, is relatively recent. The first scientific meeting on emerging viruses, held in Washington DC in 1989, was organized by Stephen Morse from Rockefeller University [1]. This field has been extensively studied since then, by various renowned health institutions in different parts of the world. The terms emerging and re-emerging infectious diseases are usually used to design the following:

- *emerging infectious disease*: an infectious disease that has newly appeared in a population or that has been known for some time but is rapidly increasing in incidence or geographic range;
- *re-emerging infectious disease*: an infectious disease that has been known for some time but is rapidly increasing in incidence or geographic range.

The concept of emergence is clearly dynamic, depending on the audience and the evolution of perception and knowledge. An emerging risk stands out from background noise; the latter can be either sanitary or environmental, but also social or induced by the *media*. Emerging risks are emerged after their perception and their specific understanding by the public in several cases: known problems linked with changes of the social acceptance, known problems

changing in amplitude and/or induced by other social groups, new health problems, etc.

### *Qualitative and quantitative information*

The magnitude of the problem was recently assessed [2] in the United Kingdom. Human pathogens account for 1407 known species, of which 58% are zoonotic and over 12% are regarded as emerging or re-emerging. These pathogens that can cause “an infectious disease that has newly appeared in a population or that has been known for some time but is rapidly increasing in incidence or geographic range” have major characteristics. They are not associated with a particular type of non-human hosts, are most likely than the non-emerging category to have the broadest host range, and are associated with a wide range of drivers. The three main drivers identified are changes in land use or agriculture practices, changes in human demographics and society, and poor population health. Climate change is the last of the ten top drivers ranked by the number of pathogens associated in decreasing numbers of pathogens (*Table 1*).

The complexity of the issue is triggered when analyzing the inter-human transmission pathways. Connections between people take many forms and have increased over time with the development of modern transportation modes and the intensification of the flux of passengers. Whether for business, leisure, or recreational purposes, exchanges concern also devices, food, water, air, etc. Disease transmission is also conditioned by knowledge or ignorance regarding the various hazards, which modify individual or collective behavior, along with the associated preventive measures.

These anthropogenic factors are well illustrated by the individualism observed in numbers of citizen in the developed countries, which leads to great difficulties in the implementation of adapted and collective strategies for efficient preventive measures. The pub-

**Table 1** | *Main categories of drivers associated with emergence or re-emergence of human pathogens*

Rank*	Driver
1	Changes in land use or agricultural practices
2	Changes in human demographics and society
3	Poor population health ( <i>e.g.</i> , HIV, malnutrition)
4	Hospital and medical procedures
5	Pathogen evolution ( <i>e.g.</i> antimicrobial drug resistance, increased virulence)
6	Contamination of food sources or water supplies
7	International travel
8	Failure of public health programs
9	International trade
10	Climate change

*Drivers ranked by the number of pathogens associated in decreasing numbers of pathogens [1].*

lic's motivation and/or willingness to comply with existing prevention devices correspond to many different reasons and vary between cultural settings as, for instance, the use of personal protective equipment (PPE) in a flu epidemic in Japan vs France.

Social perception and acceptance of risks are usually maximum when the risk is irreversible and depends, to a great extent, on the strength of the social agreement between citizen and the decision makers (public's confidence). For the latter, economic considerations and "acceptable" costs are central, thus they are faced with the necessity to resolve the following question: how to optimize preventive actions, impact and cost when provisions are not robust enough?

The complexity reaches its peak when one takes into consideration the fact that World of the 21<sup>st</sup> century has to be well understood as a global community.

The impacts of climate on water are important, both in quantitative (heat waves and extreme rainfall can affect the flow and frequencies of river floods) [3] as well as qualitative terms (physico-chemical and biological characteristics). The fact that water plays a central role in the epidemiology of many infectious diseases, whether bacterial, viral or parasitic, is well established [4]. The transmission of pathogen agents can occur through direct exposure, when drinking water (polio, cholera and other diarrheal diseases), eating food (typhoid), practicing various recreational activities like aquatic sports or swimming (cyanobacteria, free amoebas), working (leptospirosis) or inhaling particles that can develop in cooling towers (*Legionella*). Besides transmissions by plume of industrial or tertiary cooling towers, other human activities, like irrigation or fishing are prone to be central in the transmission of pathogen agents via water: malaria and leptospirosis for irrigation, cholera and other vibrios for fish or shellfish consumption [5]. The exposure matrix also includes another transmission mode where water plays a key role: inoculation of the pathogen agent to humans via a mosquito bite. Thus, the effects of water can

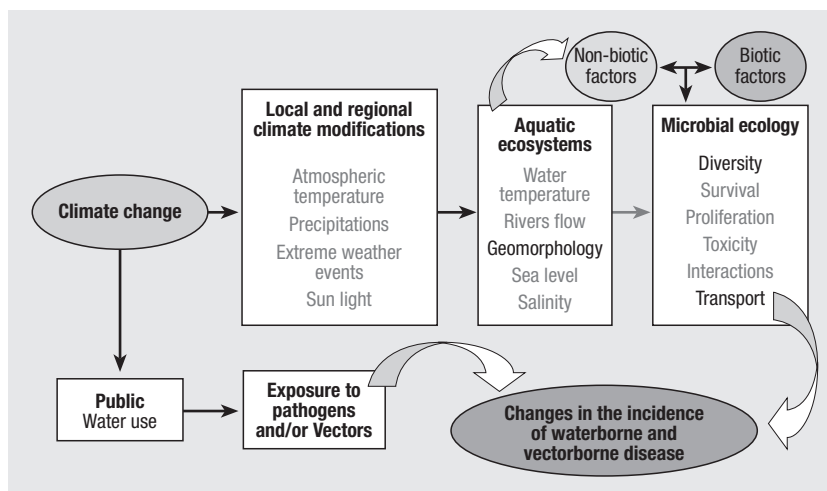
also occur during the different steps of the development of vectors. The diseases transmissible by water, as well as those vector borne, are one of the major causes of morbidity and mortality worldwide [6].

Climate impacts on water can have effects on diseases linked to water by inducing modifications on the density of microbes, the different steps of their development and the different phases of transmission of these pathogens (*Figure 1*). The proliferation of microorganisms present in aquatic ecosystems, their survival, pathogenicity, as well as the numerous interactions they can establish in their environment, are among the main biotic factors identified. Additionally, their dispersion rate in the environment, which can have an influence on human exposure, can be modified by some climate events, style of living and public behaviors. The role of this total set of factors on the different phases of the diseases linked to water's cycle, finally translate in their incidence rate, which often is characterized by marked seasonalities [7].

Beyond the modification of the pathogens present in the environment and their dissemination, social dynamics surrounding water can also be impacted by climate change, thus potentially induce modifications in exposure. These dynamics must be explored by multi-disciplinary teams properly trained to understand and analyze the different roles played by the different actors. Juridical, social, demographic aspects, besides public perception, and social attitudes pertaining to the uses made of water, are to be investigated in depth [7].

## DESIGN OF THE STUDY

The discovery of antibiotics, and of immunization, has represented a revolution in the natural evolution of infectious diseases. The battle against many deadly diseases was considered won, for many years, causing a sense of victory that may have been responsible for a detrimental lightening of control measures.



**Fig. 1** | The different steps in the effect of climate on the micro-organisms.

The design of this study was shaped to encompass various fields with an underlying decision-making driven target. The main focus – that is public health planning to protect the population from emerging or reemerging pathogens in France – has a scope that covers examples from both developed and developing countries. Additionally, the links between health and the environment, particularly obvious in the case of infectious diseases, has put climate change and its consequences (extreme climate events in particular) at the center of the study. Thus, the diseases were selected for the case studies with the following criteria: a direct or indirect role played by water in the development cycle of the responsible pathogen.

In France the distribution of deadly infectious diseases is not homogenous in the country, even though some diseases are present on the whole territory. The country, comprised of territories located in various parts of the world (Europe, the Caribbean, the Indian and Pacific oceans), is also subjected to contrasting climate patterns. Tropical infectious diseases, present in many developing or emerging countries, are generally present in most of the French overseas territories (Guadeloupe, French Guiana, Martinique, La Réunion, Tahiti, New Caledonia, etc.). Thus, France needs to take this fact into account when shaping its National Public Health planning and anticipate the emergences and re-emergences of these pathogens which ultimately may cause global threats.

Three vector- and one water-borne diseases circulate in the regions where the aforementioned islands are located, notably the Americas. They are the object of the following case studies, constructed on the same format to withdraw from a systematic analysis of available data, reviews of existing surveillance systems, results of disease evolution modeling, when conducted, and the strengths and weaknesses – on the whole to identify relevant recommendations.

## CASE STUDIES OF THE SELECTED DISEASES

### *Malaria, dengue and chikungunya*

Respectively transmissible to man by four types of *Plasmodium* for malaria [8], *Flavoviruses* for dengue [9], and an arbovirus called *Togaviridae* for chikungunya [10], these three vector-borne diseases are present in some French overseas territories mentioned earlier. The vectors themselves have a wider distribution throughout the country, and both the *Anopheles* and *Aedes aegypti* can be found on the country's mainland.

Among the ten top drivers cited by Woolhouse and Gowtage-Sequeria [2], the following three are essential, on a public health perspective regarding the object of this paper: pathogen evolution (e.g. antimicrobial drug resistance, increased virulence), international traveling, and the failure of public health programs. Climate change is the other important factor to consider when analysing the issue in the specific territories that we want to focus

on: Martinique, Guadeloupe, French Guiana in the Caribbean Region [11].

In recent studies [12], solid facts have been presented demonstrating that Latin America is vulnerable to the impact of climate change on water. We will stress, in particular, the following statements, extracted from the aforesaid work:

- climate change affects water supply and availability, the trend being towards an increase;
- climate change does not only affect human population but has also significant effects on ecosystem's integrity and the survival of species under stress;
- warm sea water in the Caribbean basin will destroy corals, fisheries and increase vulnerability of coastal areas;
- the cost of adaptation is likely to be much higher than the cost of mitigation in energy intensive nations.

*Data, surveillance systems and modeling.* - Widespread programs have been implemented globally, and especially on the African and Asian continents, in order to alleviate the burden of diseases on the concerned populations. Malaria has been eradicated from many countries, including France, thanks to progresses in preventive, diagnostic and therapeutic tools and efficient vector control programs. Unfortunately, the progresses achieved to date are jeopardized, and today the world distribution of the disease shows disturbing come-backs.

In Colombia, the incidence of malaria has doubled since 1970 and the data collected [12] show linkage with El Nino Southern Oscillation (ENSO), thus climate change. It has been estimated that 20 million people live in areas where the mean temperature range between 15 and 26 °C and that within these areas, an increase in mean temperature of 2 °C is likely to result in a significant increase in the exposure to malaria and dengue. The same phenomenon most likely applies to chikungunya, but in undetermined quantities.

Surveillance systems exist, both at the French national and supra-national levels (CAREC, WHO) for the three diseases.

Malaria is endemic in French Guiana and Mayotte, and the mandatory notification applies for indigenous cases nationally and imported cases in the French Departments of the Americas (FDA). The disease was endemic in the Camargue region up to the early 20<sup>th</sup> century, and autochthonous transmission occurred in 2006, the vector *Anopheles hyrcanus* being present on site. Data collected by the Caribbean Epidemiology Center (CAREC) [13] for its 21 member countries show no trend towards a decrease of reported indigenous nor confirmed imported cases in the islands, between 1980 and 2005. Unfortunately, information regarding the cases reported in the FDA are not included in that data base. Modeling conducted in order to evaluate the entomological risk of re-emergence in the Camargue region concluded that there is no risk [14].



Dengue circulates all year round on an endemo-epidemic mode, in the three FDA (French Guiana, Guadeloupe and Martinique), with undeniable seasonality [15]. Besides mandatory notification, the surveillance comprises the special system "Programme de Surveillance, d'Alerte et de Gestion des Epidemies de Dengue en Martinique" (PSAGE), which also covers chikungunya. During the four most recent epidemics that occurred in Martinique, the number of cases have been estimated at the following levels: 6000 in 1995; between 16 000 and 17 000 in 1997; between 26 000 and 27 000 cases in 2001; between 13 000 and 14 000 cases in 2005. Data published by CAREC show no trend towards a decrease in either reported or confirmed cases [13].

Chikungunya emerged on the island of La Réunion in 2005, and on April 24, 2006, was added to the list of diseases to be mandatorily notified [16]. The reporting concerns both indigenous and imported cases. No data was found on CAREC's web site concerning the disease.

In Italy, public authorities have assessed the existence of a risk of transmission of chikungunya in the Emilia-Romagna region. Thus, a regional plan which included an integrated strategy for both chikungunya and dengue has been elaborated [17, 18].

#### ***Cholera and other diarrheal diseases***

Climate change is one of the ten top drivers of emergence for cholera and other diarrheal diseases, whether they are due to bacterial (*Escherichia coli*) or viral (Rotaviruses) agents [19-22]. Water- or food-borne gastroenterological disorders have obviously a direct relationship with aqueous media. The fact stressed earlier concerning the vulnerability of Latin America to the impact of climate change on water can be extended to cholera and other diarrheal diseases even though the study conducted was not extended to these health hazards.

#### ***Data, surveillance systems and modeling***

The global surveillance system for cholera, coordinated by the WHO, provides historical information on the number of cases reported worldwide. The data processed for 2004 show that the global burden of cholera remains alarming: 101 383 cases reported, with a high death toll (2345 cases). Reporting concerns 56 countries, the majority (31) located on the African continent, followed by Asia, with 12 reporting countries, Europe (7) and the Americas (5). Concerning the Americas, the analysis of recent data published by the Pan American Health Organization (PAHO), shows that the disease is present in Canada, the United States, Brazil, and France.

Data on cholera and other diarrheal diseases are also collected and analyzed by CAREC. The number of cases of cholera reported by the member countries shows a clear trend towards rapid decrease, at least since 1992, not surprisingly. However, diarrheal diseases remain an important health hazard, with an

increase of cases of gastro-enteritis, salmonellosis, and different food borne illnesses, at least since 1981 (Figure 2). As for the three vector-borne diseases selected, the French surveillance system comprises mandatory notification in the whole country. Cholera and clusters of gastro-enteritis in collectivities are included in the list of 30 diseases and there is no additional system in the FDA.

## **DISCUSSION**

The impact of climate changes and global pollution on the development and/or transformation of microorganisms is no longer to be demonstrated [23-26]. The study of the parameters that preside to these transformations has been done extensively, by both scientists and physicians. Furthermore, specialists in the field of human and social sciences have also investigated these issues. In this respect, heavy trends have to be taken into account linked with quality of life of the population and modern life style of many citizens: global health and education, hyper-concentration of the world population in mega cities, working conditions in factories, offices and other work places, shopping in hypermarkets, massive population transportation in subways, buses, air planes, wide spread use of air conditioning, etc.

Besides the aforesaid factors, additional ones are crucial for an "accurate" mastering of any pandemics: the quality of the relationships between politicians and/or Governmental Bodies (Ministry of Health for example), the global health system, social and health insurances, and, last but not least, the public. This general heuristic context needs the development of anticipation procedures, the knowledge of prevention perception by the public for short, medium and long term actions, the association with stakeholders in order to support the efficiency of any actions through the necessary confidence between citizens and State representatives. Even if not extensively developed, the need to reflect on and investigate in depth the mechanisms that explain how medical knowledge, action in public health and society deal with each other appears to be crucial in order to reduce the risk of epidemics in the world. The underlying question is how a dialogue may be realized between various minorities, expressing mixed, conflicting, or firm beliefs, and furthermore, the majority of them, carrying floating opinions [27].

#### ***Strengths and weaknesses***

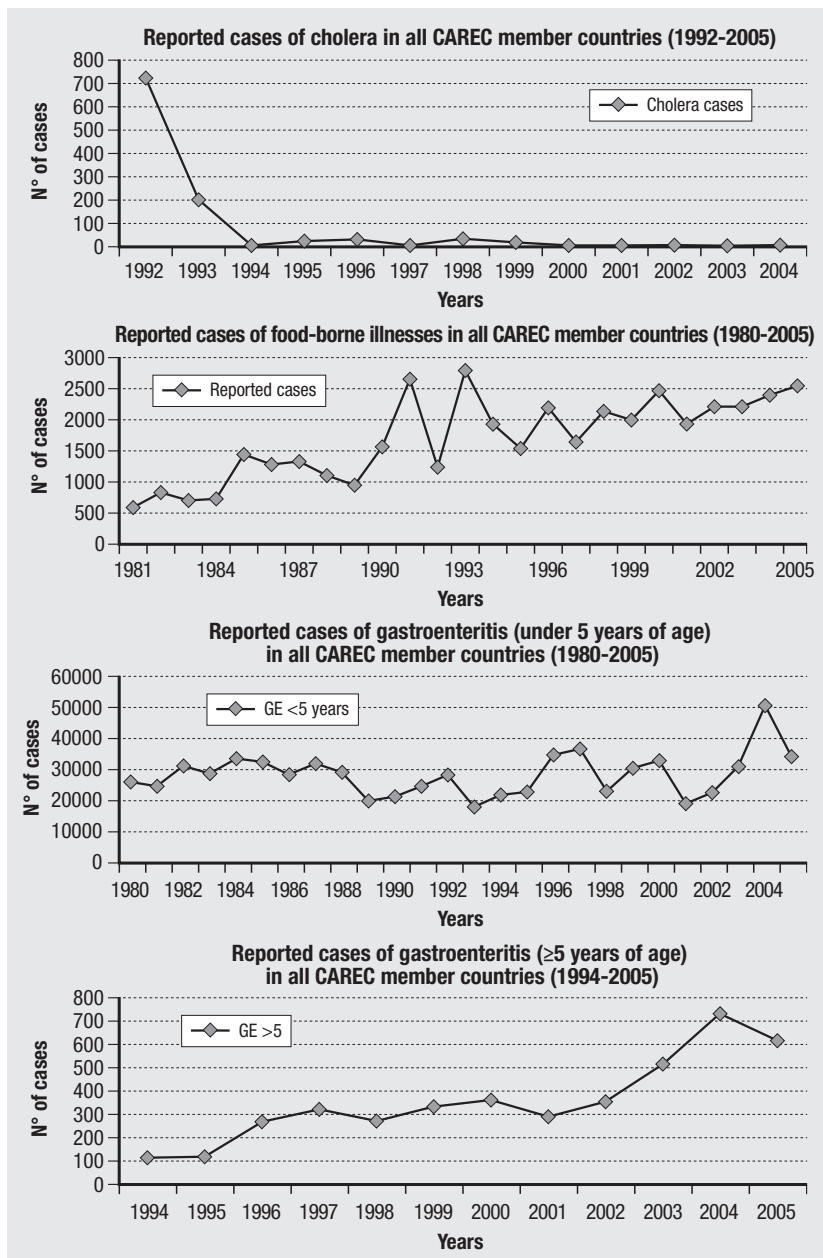
Generally, good surveillance systems exist and have been adapted to emerging diseases, but long-term and also crucial geographic data are missing. Time-scale mastering is a key factor for the conception of a good alert system (e.g. identification of clusters). This function, generally under the authority of more than one ministerial department, requires the implementation of meta-analysis. But, who is able to conduct such a complex task at the international scale?

Many sources of scientific information are available, including the existing new technologies of information

and communication like the Internet. Anticipation strategies for possible epidemics require the use of robust models in order to design different scenarios for prevention and control measures, and to associate feedbacks that include sociological, ethical and historical inputs, among others.

Malaria is the archetype of the infectious disease for which large national and international control programs have been successfully implemented. However, the results are no longer satisfactory, as the disease is spreading to territories previously declared disease-free. Eradication, as a goal, although not set to be achieved worldwide as for other pathogen agents (smallpox, poliomyelitis, measles), was well on the way from a vast range of territories, mainly in tempered countries.

There may be a trend to either over- or underestimating risks, when it comes to evaluate the health risks linked to the development and evolution of the natural history and circulation of pathogens in the global community. However, accurate forecasting is somewhat a difficult exercise. Many interdependencies exist between the social, technical and scientific components inherent to health planning, and the complexity is increased, or worst, can be induced by using non-robust models. Nevertheless, public's confidence, reflected by the strength of social agreement between citizens and the decision makers, is a key issue and should remain the goal. Indeed, today, the public demands an "as low as reasonably achievable (ALARA)" type of leadership, as expressed in the precautionary principle, which has been inscribed in the French Constitution in 2005.



**Fig. 2** | Cholera and other diarrheal diseases in CAREC (source CAREC surveillance database).

### Recommendations

Targeted at many stakeholders, not only, but with a special focus on France, a set of seven recommendations are drawn from the lessons learnt during the analysis of data collected on the four diseases.

*Revisit public health program planning* to emphasize representativeness by implementing the following proposals:

- support evidence-based health planning, shaped after a field evaluation and built on the needs identified and expressed by the targeted population;
- focus on fundamental aspects, like common sense, empirical knowledge, field level expertise, when assessing the population needs;
- modernize the information systems, notably by developing Geographic Information Systems (GIS).

*Implement a more fluid and integrative approach to program management* in order to optimize the political steering, by including the following dimensions:

- ensure a bi-directional information flow: bottom-up first, then top-down;
- consider health and the environment as inclusive of each other;
- allow frequent and systematic interactions and feedback between the various components and phases of the planning.

*Develop solid and robust prospective tools* along with the relevant trained human resources.

*Reconciliate the different stakeholders' agendas in order to recover trust*, focusing on the field level and adapting the speed on the bottom-up information flow. Public's confidence, reflected by the strength of social agreement between citizens and the decision makers, is a key issue and should remain the goal.

Support the French overseas territories in the development and implementation of regional partnerships, notably with the institutions of which France is a member country:

- in the field of public health and epidemiology, collaboration for inclusion in the CAREC data base should be investigated, while tightening the partnership with PAHO would also be extremely useful;
- in the field of research and health politics, dialogue with the Caribbean Community (CARICOM) and Organization of American States (OAS) is likely to be fruitful, in particular for participation to the Global Island Partnership (GLISPA) and the strategy on climate challenges in Latin America.

*Develop health and the environment joint policies* to correct the fact that today, notably in France, policies related to the environment, on one hand, and health policies, on the other, are too often elaborated without enough reciprocal consultation:

- policies concerning the environment should be of a broader spectrum, in order to take into account the links between the different biological medium: in that respect, it is crucial to have an integrated approach in the management of soils and water, and they should systematically include the health dimension;
- the Ramsar Convention, an intergovernmental treaty adopted in 1971 and ratified by France in

1986, providing the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources, and the European network "Natura 2000" for the preservation of biodiversity, should be studied on a sanitary point of view;

- European, and to a certain extent the new French National Plan for health and the environment [28], are promising beginnings but progresses are still to be accomplished.

*Promote and support research on pathogens and their environment*, including in aerobiology, since it has been established that ecological understanding of pathogens and associated non-pathogens in their environment may be the key to predicting the effect of climate change on infectious diseases [29, 30]:

- efforts must be undertaken to increase the scientific knowledge available on the ecology of pathogens by developing research in that area;
- it is in particular necessary to target these researches on the behavior of microorganisms in the different biological medium, notably in air by developing aerobiology [31], along with research on the interactions between microorganisms and their physico-chemical environment.

### CONCLUSIONS

Among the 13 conclusive lessons learnt from severe acute respiratory syndrome (SARS) [32], we highlight the six following ones, as applicable in conducting the present study:

- transparency is the best policy;
- public health is serious business;
- human right issues must be attended to;
- partnership works, but partners need to clarify and agree on their respective roles;
- modern mode of communication dramatically changes the way we work;
- with national disease surveillance systems in despair, informal avenues of reporting must be taken seriously.

Similarly, we think that the eight liabilities listed hereafter, accounting for loopholes that regulators must close [33], could be, to a certain extent, extrapolated to decision-making in public health in general, and to the use of information for public health program planning and the implementation of prevention and control measures: short-sightedness, concealed science, the known minimum, privileging secrecy, inconsistent estimates, hidden assumptions, missing benchmarks and risk-free proxies. However, we also wish to stress that the possible following promising decisions taken in France have been identified:

- a program was recently established by law to develop research on infectious diseases and the health risks linked to climate change;
- the High Council on Public Health has released an advice on the subject on November 27, 2009 and established a special working group in charge of investigating emerging diseases.

Nevertheless, we strongly believe that, beyond the public health issues, the following important matters are at stake:

- global social cohesion and a certain way of life;
- global security and a societal organization enabling real democratic environments;
- global adaptation of new technological progresses to the human species and not the inverse paradigm.

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### Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

### Notice

This paper develops an analysis that is solely the opinion of its authors. The discussion, recommendations and conclusions do not represent the position of their institutions.

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