Impacts on Health of Climate Change

Executive summary

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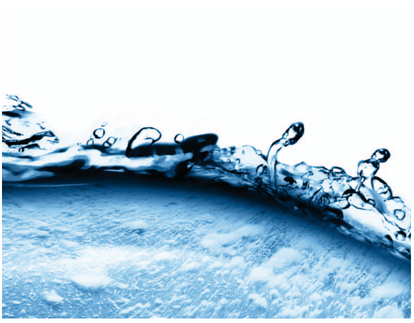


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Introduction

Currently, there is a general scientific consensus regarding the idea that human health and well-being are closely related to environmental quality. Over the past few years, the issue of climate change as determinant in environmental factors, and therefore, in population's health, has become especially relevant, giving way to several health strategies, both on the part of different countries' public administrations and international entities.

The elements that determine public health are quite diverse and interact in a complex fashion. As such, it is a priority to attain further knowledge regarding their impact and the population's vulnerability to them, particularly insofar as human health is concerned. Within this context, studying the impact of climate change on the health of Spanish society will allow the design and integration of adaptation measures in health management and planning policies, as well as to develop protective and preventative strategies for its effects, insofar as is possible.

This report, elaborated by the Observatory of Health and Climate Change, describes a series of environmental issues with a recognised and direct influence on health and well-being. It addresses relevant aspects such as the effects of extreme temperatures manifested in cold or heat waves, air or water quality and the possible spreading of diseases on the population's morbidity and mortality.

The World Health Organisation (WHO) has warned that the health of millions of people could be threatened by the increase of diseases such as malaria, malnutrition and other diseases transmitted through water. In the majority of scientific studies, and as shown in this report, the effects that the climate change will have on the population's health are projected. It should be noted that Spain is especially vulnerable to climate change due to its geographical location and its socio-economic characteristics.

In September 2013, the Intergovernmental Panel on Climate Change (IPCC), has approved Volume I of the Fifth Assessment Report (AR5 WGI-) which describes and summarizes the current knowledge on physical scientific aspects of the climate system and climate change. This report confirms that the global warming of the system is certain and that human influence is the dominant factor in this change, and supplements with its results this publication on climate change impact on health, offering an opportunity to continue working in this area and providing a solid base for the implementation of sector policies in the field of adaptation to climate change on health.

Notwithstanding, it is important not to forget that the data available today predicts future situations under particular premises regarding climate, socio-economic conditions and vulnerability of the population. As such, the projections may notably differ between models, which forces to work with certain degree of uncertainty.

In order to fight and adapt to climate change, continued scientifical and technical assessment giving responses to the effects that climatic change has and the effects it may have on health is mandatory. The purpose of this report is to compile the most current evidence regarding prioritised environmental matters and to provide the technical-scientific support necessary to make accurate decisions to face climatic change.

From the Ministry of Health, Social Services and Equality and the Minister of Agriculture, Food and Environment, we would like to thank the constant effort and generosity of the experts who participated in the preparation of this document.

In closing, we would like to encourage all of society to actively participate in the challenge of adapting to climate change, and the scientific community to continue with their valuable researching efforts.

Director-General of Public Health,
Quality and Innovation

Director-General of the Spanish
Office of Climate Change

Climate Change and Public Health

The scientific community's consensus regarding the existence of a global climatic alteration is a fact. Without a doubt, the studies and research carried out in this field have been determinant in reaching this conclusion. It should be noted that the Fourth Evaluation Report from the Intergovernmental Panel on Climate Change (IPCC) from 2007 concluded that the warming of the climatic system is unequivocal and that there is 90% certainty that it is due to human action.

Climate change cannot be considered exclusively an environmental phenomenon. Rather, profound economic and social consequences should be considered, especially those related to public health. The international community has not distanced itself from this topic, and in 2008, at the 61st WHO World Assembly, 193 countries assumed the urgency of developing health measures integrated in climate change adaptation plans, thereby recognising their impact on public health.

Several determining environmental and social factors regarding health will be affected by climate change; modifications that make it a significant challenge for action within the realm of public health. The conceptual model summarising impacts states that regional climatic changes, extreme events and heat waves, precipitations and temperatures, are factors that will influence agro-ecosystems, demography, socio-economy, biological contamination methods and the dynamics of disease transmission. In response to this new 21st century challenge for public health, numerous initiatives have been implemented to identify human vulnerability and health risks derived from climate change, to prepare to respond and to propitiate greater resilience for communities against its effects.

In Spain, a country vulnerable to climate change's effects, just like the entire Mediterranean coast, actions regarding public health support, integrate and take into consideration dynamic programmes and actions from WHO's Regional European Office and from the European Union. On the other hand, the National Climate Change Adaptation Plan, approved in 2006 by the Climate Change Policy Coordination Commission and the National Climate Council is the national reference framework. This National Plan, headed by the Ministry of Agriculture, Food and Environment (MAGRAMA) has identified the health sector as priority for sectorial evaluation in their second work programme.

The Climate Change Health Observatory is created within this framework as an instrument to analyse, evaluate and track the effects of Climate Change on public health and on the National Health System, allowing the execution of adaptation policies to reduce the Spanish population's vulnerability to climate change. The intent of this text is to synthesise the Report on the Impacts of the Climate Change on Health.

As a continuation of the previously mentioned model, the main known impacts of climate change on health are related to extreme thermal events, atmospheric contamination, morbidity and mortality related to temperatures, with diseases transmitted through water, food, vectors and effects on infections, injuries, mental health, nutritional elements, and of other sorts. However, it is important to also consider the potential influence that adaptation measures have, both on essentially climatological factors as well as on social, environmental, demographic and economic factors, and consequently, the impacts on health. It may be concluded that climate change's impacts on health, as already seen, may be brought about either directly or indirectly.

On the other hand, current evidence shows that effects on health may be positive and negative. For example, a positive effect is the increase in temperature, which may decrease the survival of certain disease-transmitting vectors, or reduce the number of intense cold episodes, particularly in certain regions. Negative factors include the prediction of an increase in child malnutrition rates in determined geographic regions, the increase in episodes of heat waves, an increase in water and food-borne diseases, and a potential increase in allergic conditions.

The nature and scale of the end impacts will depend on the adaption capability of the population, society and health systems, as well as the actions implemented and access to health systems.

Taking into account previous studies carried out in our country regarding climate change's effects, as well as academic and researchers' opinion, public administrations, and associations relevant in this subject, priority health effects have been identified as those related to temperatures and extreme events, air and water quality, and vector-borne diseases.

The purpose of the Report Regarding Climate Change's Impacts on Health is to provide an update on scientific knowledge, a compilation of actions carried out on a local, national, regional and global level in this regard, as well as a recounting of main uncertainties that must guide posterior research at the disposal of managers and citizens.

The methodology used to prepare this Report was based on revising scientific evidence, through relevant and updated bibliography (in scientific literature databases and publications from specialised entities and agencies), as well as reaching consensuses between experts from the four work groups created for each of the areas of analysis.

The Report has several initial introduction and background chapters regarding the topic, and four individualised thematic chapters for each prioritised area.

Impact of climate change on temperatures

Extreme temperatures and health

The increase of greenhouse effect gas levels has already caused global warming by more than 0.5°C, and an increase of at least another 0.5°C is guaranteed over the next few decades, even if the concentrations of these gases do not increase. Until the year 2006, the last 11 years were determined as the warmest since 1850, as per instrumental records of temperatures on the world surface (IPCC 2007). In Spain, in the summer of 2012, average temperature reached 24°C, which means 1.7°C more than the normal average (reference period, 1971-2000), being the fourth hottest summer since 1961 (AEMET 2012).

Projections show an increase in superficial air temperature for the year 2100 between 1.8°C and 4°C, which is a very fast change in rhythm, and implies a wide range of uncertainties in the relatively near future, with potential environmental, economic, social and health consequences.

The most probable scenarios for the upcoming years will be characterised by an increase in climatic extremes of all sorts (heat waves, draughts, intense precipitations, etc.) which will be quite different and have different intensity, depending on the geo-climatic characteristics of each zone. In Europe, predictions indicate an increase in temperature and draught frequency, as well as the generation of intense heat waves and increase in the frequency of uncontrolled fires.

In Spain, predictions (Moreno et al. 2005) indicate a progressive increase in average temperatures over the course of the century, significantly higher in summer than in winter, lower annual accumulated precipitation, higher amplitude and frequency of monthly thermal anomalies in comparison with the current climate and a higher frequency of days with extreme temperatures, especially in summer. In 2010, the *Agencia Estatal de Meteorología* (Government Meteorology Agency) (AEMET), in their project "*Generación de escenarios regionalizados de cambio climático en España*" (Generation of regionalised scenarios of climate change in Spain) (AEMET 2010), makes different projections according to the different climate change scenarios, and predicts a higher increase in maximum temperatures during summer months, and a lower increase during winter. It is estimated that this effect will be more acute in the interior regions of the Peninsula.

The definition in public health of heat and cold waves brings serious difficulties (Montero et al. 2012). Some of the limitations of the definition of heat wave are relative to the parameters used that synthesise several variables in one sole mathematic algorithm, and the fact that they are merely considered as climatological conditions without taking into account population health indicators. To define a heat wave, efforts must address the search for a threshold temperature through consistent epidemiological studies. This way, adopting prevention plans based on exceeding the mentioned thresholds will imply a decrease in impacts of high temperatures on the population's health.

In Spain, in 2004, the *Plan Nacional de Actuaciones Preventivas* (National Preventive Action Plan) for excess temperature effects, was implemented. Its objective was to prevent mortality derived from this excess and for which alert levels were defined, based on exceeding threshold temperatures and the persistence over time of excess temperature.

Effects on health

The relation between health and temperature is not unchangeable. Rather, it is regulated by a complex number of economic, social, cultural and health variables (Basu 2009). The relation between temperature and mortality tends to have a "V" or "U" shape, with a temperature of minimum incidence that varies from some places to others (Sáez et al. 1995; Ballester et al. 1997; Alberdi et al. 1998; McMichael et al. 2008) and that probably depends on the population's adaptation to the temperature range to which they are exposed (Curriero et al. 2002; Díaz et al. 2006). The increase in morbidity and mortality related to extreme temperatures is one of the climate change's direct effects.

An especially important variable is the aging index. With a higher aging in population, it seems that the effects of heat waves on health appear at less elevated temperatures.

Within the framework of the European project PHEWE (Assessment and prevention of acute health effects of weather conditions in Europe), which includes Barcelona and Valencia, the possible increase of mortality on the horizon for the year 2030 as per IPCC scenarios has been studied and the conclusion is that the average fraction attributable to deaths from heat would be 2%, with greater impact on Mediterranean cities (Baccini et al. 2011), and predicting that this phenomenon will increase in the future according to the predicted increase in the frequency and intensity of heat waves. Other works have obtained greater increases in mortality (Dessai 2003; Donalson 2002; McMichael 2002; Ostro et al. 2012).

Effects will be more and more important, and the impact of heat waves which will be more frequent and intense will be higher for two reasons: The temperature will be more and more elevated as a consequence of the climate change, and the trigger threshold for mortality will be lower due to the population's aging.

Regarding cold, it should be noted that the relation between cold and health is also conditioned by social, economic and cultural factors, the evolution of which is unknown in future climatic change scenarios.

There is a greater impact of cold on mortality in places with milder winters than in places with harsher winters, due to the physiological adaptation to low temperatures and the infrastructures of homes, which make conditions for fighting against cold better in places accustomed to cold waves than in those where they are less frequent (Eurowinter Group 1997).

The increase in average winter temperatures need not imply a reduction in the frequency or gravity of extreme cold episodes.

It is considered that the increase in mortality due to heat will be greater than the slight reduction to be expected from winter deaths (Kalkstein and Greene 1997).

Vulnerability

To identify the most vulnerable areas to the mentioned extremes, places that can expect a greater incidence both in frequency and in intensity of thermal extremes should be considered. Additionally, population aging should be taken into account, since biological vulnerability will result into a greater effect on mortality in areas where the elderly population proportion is greater.

Other biologically vulnerable population groups should also be considered , such as children and people with sicknesses and/or determined previous treatments, as well as those vulnerable due to social, professional and economic conditions, for example, workers exposed to excess temperatures and the most socio-economically disfavoured groups (Davis et al. 2003; Michelozzi et al. 2006; Carson et al. 2006). Both, the improvement of socio-economic conditions and actions to protect and prevent effects from excess temperature contribute to the mitigation of effects. A project carried out in our country concludes that, despite detecting an economic increase and improvement of all types of infrastructures, the population's age, measured by the number of people over 65 years of age, prevails over the socio-economic improvements.

Adaptation

The main adaptive options proposed on a national and international level include preparing *in situ* alert systems for possible thermal extremes, improvement of urban planning, including bioclimatic constructions, providing relevant and opportune meteorological information, elaborating prevention plans, providing information to the population regarding measures to adopt and training and improvement of health services.

Main uncertainties and lines of work

There are multiple uncertainties regarding how the climatic change is going to affect the relation between extreme temperatures and health.

Regarding temperature, the uncertainty lies in the climatological models used by different emissions scenarios.

On the other hand, we are facing these uncertainties related to the association between temperature and mortality, wherein multiple factors influence, such as population pyramid, socio-economic conditions and the existence of vulnerable groups. In addition to all of these, we face the difficulty of estimating how they are going to behave in the future.

Demographic evolution bears the least uncertainties: it is estimated that in Spain, population older than 64 years will grow by 19.2% over the next decade (INE 2009). A change will happen regarding temperature thresholds, after which an increase in mortality from heat will occur. The uncertainty is greater if the indicator being evaluated is the population's morbidity due to a temperature excess.

Evolution of socio-economic conditions is uncertain, particularly under the current conditions of economic crisis and their close relation to the provision of public health services.

Another great unknown element lies in adaptation to the climate change. Evaluation of prevention plans is still insufficient to determine the best strategies.

The main lines of work proposed to minimise uncertainties, as far as possible, include:

- Analysis of atmospheric conditions at the smallest meteorological scale possible, allowing a prediction with enough time beforehand, as well as a prediction of the duration and intensity of the extreme meteorological event.

- Studying physiological adaptation mechanisms and the role socio-economic variables play in adaptive processes.

- Studying the relation between winter and summer mortality.

- On a local scale, researching mortality and morbidity rates behaviour associated with extreme temperatures, emphasising the behaviour of each population group as to temperature and its measurement in terms of hospitalization.

- Evaluating the effectiveness and operation of action plans in the face of thermal extremes.

- Developing properlyl-defined action protocols for thermal extremes, both in health promotion and in health assistance.

Impact of the climate change on water

Water quality and health

Global warming observed over the past decades is associated to variations in certain components of the water cycle. These variations, included in the study "Climate change and water", carried out by Work Group II from the IPCC, include changes in patterns, intensities and extreme values of precipitation; in the generalised fusion of snow and ice; in the increase of atmospheric water vapour and the increase in evaporation and variations in soil moisture and run-off.

Predictions estimate generalised losses in glacier mass and acceleration in the reduction of the snow cap, thereby decreasing water availability and hydroelectric potential, altering the seasonality of flows in regions supplied with snow water from main mountain ranges, and currently where more than a sixth of the world population lives. An intensification in episodes of torrential rains is predicted and flooding, from a descent in river volume flows and more severe and frequent draughts. Coasts will be exposed to greater risks related to an increase in the sea level, greater salinization of underground water and human pressure.

It is expected that climate change will intensify the stress currently suffered by hydric resources, due to population growth, economic change and land use, and particularly, urbanisation (IPCC 2007). Hydric resources which we believe to be guaranteed today may be compromised in the future if appropriate measures are not taken (EEA 2011).

In Spain, climatic scenarios predicted by the National Climate Commission in the Water White Book predict a slight decrease in average annual precipitations and an increase of temperatures, which would give way to a decrease in total run off. Predictions of climatic models point indicate an intensification of dry periods in summer, and a total precipitation in winter similar to the current one, although it would be concentrated over a lesser number of months.

South-eastern territories on the peninsula, the Guadiana Basin, the Ebro Valley and archipelagos would be the areas where the impact would be most severe on resources, precisely the resources which already bear the greatest hydric problems.

It is foreseeable that the increase observed in water variability will be maintained over the next decades for Atlantic basins.

Peak flows of the Ebro and Duero rivers may undergo sudden thaw episodes, consequent to variations in winter and spring temperature.

Basins on the Mediterranean and the interior of the peninsula may increase the irregularity of swells and draught regimes, and promote the generation of swells, although with a high level of uncertainty.

A generalised reduction in water resources is predicted for the entire territory, and it appears that this will be accentuated as the 21st century goes by. On the other hand, the climatic change will also increase the probability of cyanobacteria occurrence due to an increase in water temperatures (Paerl and Huisman 2008).

Effects on health

The impact on health as a consequence of the climatic change in water is produced indirectly. It is predicted that the intensification of alterations on the water cycle will highly impact water quality, and therefore, the health of those who consume it, those who do not have access, or those who do have access but do not have adequate treatments systems to guarantee sufficient quality of water for consumption.

Among the effects on health of draught episodes, a greater risk should be noted of water-borne disease risk, lesser agricultural production capacity that in certain regions in the world may cause an increase in malnutrition and mortality, and variations in the incidence of vector-borne diseases. Additionally, these episodes are frequently associated with dust storms that have a respiratory effect on health. With dust, the air may also transport a higher concentration of breathable particles, fungi spores and bacteria that may affect health (IPCC 2007).

Draught is also associated with changes in use and topsoil, and with the occurrence of forest fires that may cause changes in the habitat of animal species that act as reservoir of pathogenic agents. Finally, draught is also related with a risk of health effects due to an increase in the chemical and pathogenic load of river flows.

The increase in water temperature is also related to health effects. Although it is unclear how phytoplankton will respond on a global level to the temperature increase, a potential consequence could be the selection of the best-adapted forms to the new environmental conditions (De Senerpont Domis et al. 2007). In this sense, there is evidence that brings us to conclude that cyanobacteria may benefit from the increase in temperature (Reynolds 2006; De Senerpont Domis et al. 2007; Paerl and Huisman 2008), particularly in reservoirs and lakes where noxious algae may grown, although this may also occur in marine waters.

Cyanobacteria may pose a risk to public health due to its toxic potential on human beings, with a wide range of harsh, chronic effects (Sant'Anna et al. 2005) and due to the different possible methods of exposure and transmission.

In general, within a context of an elevated development level, the threat to health due to the proliferation of cyanobacteria is quite small. The risk that the supply of consumable water is contaminated with the toxins they produce is low.

Health effects from flooding include death, injury, infectious diseases, toxic product contamination, shifting and mental health problems (Greenough et al. 2001; Ahern et al. 2005).

Flooding may cause biological and chemical contamination of water flows and courses. Overflow of sewage systems, along with rain water discharge, affect the quality of recipient waters (Even et al. 2007), sometimes in a fatal manner, for aquatic life forms. Additionally, the quality of bath water near this waste may deteriorate very quickly. Biological contamination is a mid-term risk for the emergence of infectious diseases.

Flooding may cause contamination in river flows, agricultural and livestock soil with chemical products, heavy metals and other dangerous substances coming from storage spaces and warehouses, or chemical products found in the environment, such as pesticides (IPCC 2008).

In other cases, contamination of river water, and later on, flooded ground, is the result of mobilisation in contaminated areas at the founts of the rivers.

Changes in origin of water quality influence their treatment, in such a way that coagulation and flocculation processes may be worsened. The use of greater doses of oxidants and disinfectants (chlorine, chlorine dioxide, ozone, etc.) may be required. This, along with the possible existence of greater levels of precursors, may have an influence on the increase of the potential for trihalomethane formation in treated water.

In the case of draught, and especially in the case of restrictions, supplementary controls must be carried out in addition to customary, routine ones, and control at water network delivery points must be intensified. To select these additional controls, determined by the competent authority in a draught situation, there are tools such as evaluation systems and risk management, Water Health Plans and the Critical Control Points and Danger Analysis, applied to quality control both for resources and for treatment plants or the distribution network.

Vulnerability

The territory's vulnerability to variations in water resources is closely related to soil uses. With greater need for water and guarantees of use, vulnerability is greater. Under equal conditions, a territory is more vulnerable where priority use is urban supply than if it is irrigation, due to greater quality requirements. Human vulnerability to extreme events related to water resources (draughts, flooding, swells…) depends on their individual, social and environmental conditions.

On a territorial level, Spain is one of Europe's geographical spaces most sensitive to natural risks, due to its geographic position, its peninsular nature, its topography, its climatology and human occupation.

The most vulnerable areas to draught are located in territories classified with structural scarcity where the potential resource (water) is systematically lower than the consumption level, and in territories classified with economic scarcity, in the case of Spain located in the south-eastern peninsular half, some systems on the right margin of the Ebro, part of Catalonia and some islands.

The most vulnerable areas to flooding are not such exclusively due to the climatic effect, but also due to human urbanisation and occupation. The analysis of vulnerability to swells and flooding combines susceptibility to anomalous precipitation and a greater exposure of persons and goods. In Spain, the areas most susceptible to suffering these episodes are located in the Mediterranean area, the interior of the Ebro valley and areas dispersed in the interior of the peninsula, associated with small basins.

On the other hand, variations in water resources must be considered, a consequence of the climatic change with which we are concerned, as they are elements that influence other sectors that are also dependent on these resources, such as the energy, tourist, forest and agricultural sector.

Since Spain, is a country vulnerable to variations in water resources, water planning processes and specific regulations have been developed, with a high number of approved Water Basin Plans. Within the scope of Public Health, work is being carried out on promotion, protection and survelliance as to the quality of water for human consumption. The adaptive options proposed for handling hydric stress may respond to supply and/or the demand for these resources.

Main lines of work

The main research needs, and consequently, lines of work must address progress in adaption measures and in general terms, improve:

- Knowledge of episodes to improve models and projections.
- Management and handling of trans-border waters, to guarantee the quality, homogenisation of information and the inter-calibration of methods and procedures.
- Knowledge of the inter-relation between quality and availability of water in our country as a consequence of the climatic change's effect, which would allow for later monitoring and tracking.
- Carrying out epidemiological studies as to the potential relations between the climatic change and risks for water-borne diseases.
- Risk analysis for especially vulnerable areas, as well as the implementation of treatment systems for water at all supply points to evaluate the risk and determine their critical points.

Impact of the climate change on air

Air quality and health

It is estimated that atmospheric contamination, an environmental health risk, causes around 3.2 million deaths per year in the world (Lim et al. 2012). For many years now, WHO has considered atmospheric contamination as a world priority.

Important population sectors are exposed to elevated concentrations of atmospheric contaminants, with the consequent negative effects on health. It is possible to establish a quantitative relationship between contamination levels and their effect on health, particularly an increase in mortality or morbidity. On occasions, even low concentrations of atmospheric contaminants can cause adverse effects. The WHO indicates that there are serious health risks, mainly derived from exposure to suspended particles, nitrogen dioxide, tropospheric ozone and sulphur dioxide, whose concentrations may increase with the climate change (WHO 2006).

In general, effects on health deriving from long-term exposure are much greater than those observed in shorter exposures. Even though one might say that environmental legislation is causing a gradual reduction of maximum concentrations of atmospheric contaminants for the majority of those that are regulated over the past few years (Guerreiro et al. 2012), the same cannot be said for exposure over a longer period of time. Currently, attention has been directed toward this chronic exposure.

There is a growing international recognition of the importance of addressing air and climatic contamination simultaneously. The work carried out to research the climate change's impact on air quality makes it clear that this is a very complex analysis, since atmospheric contaminant concentrations are influenced by multiple factors, such as wind, temperature, topography, human activity, interaction with local weather patterns and the adaption measures implemented.

On the other hand, the increase in temperature is quite directly correlated with the increase in tropospheric ozone concentration, which by itself has elevated annual seasonality, with higher figures in warm months and important peaks during solar radiation hours. Additionally, the increase in winter temperatures produces an anticipation of blooming for some spring blooming species, lengthening their pollen season, which also increases the population's exposure time. It has been observed that species that bloom in early spring are more sensitive to global warming than species that bloom later.

In addition to their production and emission levels, concentrations of atmospheric contaminants also depend on their dispersion and transportation model, and the climatic change may affect any one of these processes.

In cities and certain industrial areas, limit values for these contaminants are exceeded with higher frequency, which means a high number of the population is exposed. In our country, recent data reports display excess in the limit values for some regulated contaminants (*Evaluación de la Calidad del Aire en España* (Air Quality Evaluation in Spain) 2011)).

One of the factors that contributes to suspended particle contamination is the high number of diesel vehicles, along with conditions inherent to a Mediterranean climate that propitiate contamination episodes, a lack of precipitation that does not eliminate sediment dust on the urban surface, and the intrusion of Saharan dust.

Effects on health

Atmospheric contamination has an effect on the appearance and worsening of respiratory and cardiovascular diseases and cancers. For adults, asthma, COPD and lung cancer are three epidemiologically important respiratory diseases, related to atmospheric contamination.

Evidence indicates that respiratory effects, especially making asthma more acute, are the main reasons for hospitalization because of atmospheric contamination (Ballester 2009). Other effects should not be discarded, especially those which may be derived from exposure over time, such as lung function alteration, an increase in allergies, immune alterations and even a risk of mortality.

On the other hand, it must be taken into account that atmospheric contamination tends to not be due to one sole contaminant. Rather, it is normally a mix, which makes it more difficult to measure exposure and health effects, and its association with pathological symptoms and/or exacerbations of previous symptoms. Additionally, we know that repeated exposure (several days) may have more serious effects than the effects from exposures on individual days. In Spain, 13,915 deaths can be attributed to suspended particle effects, and 947 to the ozone (Lim et al. 2012). According to data published by the SERCA Project in our country, if long-term exposure to $PM_{2.5}$ air concentrations was reduced to an average concentration on a national level of 0.7 µg/m^3, avoidable deaths at long-term would be between 1,450 - 1,720 in adult population.

Different studies associate short-term exposure to the ozone with respiratory morbidity and mortality, as well as with cardiovascular disease (Díaz et al. 1999). The greatest impact would be on the elderly, who habitually present a compromised state of health, so the aging of the population in our country would result in a greater impact.

Vulnerability

The majority of people are exposed to atmospheric contamination, particularly those who reside in cities.

Among the most vulnerable population groups, from a biological point of view, are the elderly, people with compromised health who suffer from chronic bronchitis, chronic obstructive lung disease, asthma, cardiovascular diseases and/or diabetes, children (Bateson and Schwartz 2004) and pregnant women. In the case of children, vulnerability lies in an incomplete development of their respiratory system, and the fact that they breathe more air per weight unit than adults. Additionally, as these are exposures in very early stages of life, they are going to have more time to develop the effects, so the damage will be greater in terms of years of life lost or years with disability. Exposure to contamination during the first year of life is associated with an increase in child mortality risk, of a greater magnitude than for adults. It has also been documented that a greater index of inequalities in child health implies greater vulnerability to the climatic change's effects.

In the case of pregnant women, results have been found that indicate an association between exposure to atmospheric contamination with low birth weight and delayed intra-uterine growth.

In the case of ozone contamination, the group of people at greatest risk would be children, young people and adults, from having spent more time outside buildings. Additionally, people who work outside or in places exposed to intense contaminant intake are also subjected to a greater risk.

It should be noted that, although the magnitude of impact on health may be slight, the impact proportion attributable to contamination is great, since all of the population is exposed.

Mitigation and Adaptation

Main options to better manage risks caused by atmospheric contamination are based on mitigation and adaptation strategies. Amongst them all, the most important measure is to decrease contaminating gas emissions. In order to achieve this, actions must be taken in transportation means, urban and industrial sectors, making efficient use of energy and the progressive use of renewable energies. These measures should be complemented with education on health, and the promotion of healthy habits, including efficient and responsible energy use.

Regarding adaptation, the main measures proposed include establishing a quality surveillance system for air and early alerts for the population when facing situations with an increase in air-borne allergen, pollen or spore levels, including meteorological and atmospheric contamination information. It is important to consider citizen participation, to encourage the development of awareness in health and air quality, since health problems related to the environment are connected to social development patterns we follow, and their solution depends on important lifestyle changes that affect broad portions of the population. On the other hand, results must go beyond the health sector and reach other sectors.

Main uncertainties and lines of work

On one hand, there are uncertainties related to the sources of atmospheric contaminants, which turn out to be a great difficulty in estimating future emissions scenarios, and in the evaluation of which, the current economic crisis and fulfilment of regulations in force must be considered. On the other hand, there are still uncertainties regarding the biological effects of some contaminants on health. Even though a concentration – response relationship has been established for particular material, this is not the case for other contaminants for which the nature of the relationship has not been sufficiently elucidated.

The lines of work proposed from a research standpoint include:

- Carrying out epidemiological studies to evaluate the impact and health effects, including the dose-response relationship, and the modifying factors of the mentioned effects.
- Research on the contaminants' action mechanisms that cause physiological damage in the most sensitive systems.
- The evaluation of potential health benefits from climate change mitigation actions.
- The development of predictive models that include predictions regarding future trends in atmospheric contamination, changes in population characteristics and variations in meteorological and climatic phenomena.

Impact of the climate change and vector-borne diseases

Climate changes can influence the frequency and distribution of vector-borne diseases on a global level, as well as the seasonal and inter-annual dynamic of pathogens, vectors, hosts and reservoirs. In fact, over the past years, an increase in autochthonous cases and epidemic outbreaks of certain vector-borne diseases has been observed in Europe (Githeko et al. 2000). Both, health-specialised international agencies and organisations have warned on this influence in vector-borne diseases (Bezirtzoglou et al. 2011).

Temperature changes, precipitations and humidity affect the behaviour, seasonality and abundance of vectors, intermediate hosts or natural reservoirs (Githeko et al. 2000). If said changes come about close to each specie's characteristic threshold, the life cycle undergoes brusque, non-linear accelerations.

Temperature is a critical factor upon which the density of the vectors and their vector capacity depend: it increases or decreases their survival, it conditions the growth rate of the vector population, it modifies the extrinsic incubation period for the pathogen in the vector, and changes the activity and pattern for seasonal vector transmission. The speed of development increases with the increase in temperature, and it may be affirmed that more vectors exist, and it is even possible that more generations per year exist. The climate change's effect on these diseases will probably be observed upon varying transmission temperature limits that generally correspond to 14 - 18°C as the lower limit, and 35 - 40°C as the upper limit.

An increase in precipitations may increase the number and quality of breeding grounds for mosquitos, as well as the density of the vegetation propitious to their development and reproduction. Floods may eliminate the appropriate habitat for an undetermined period of time. As far as draughts are concerned, in wetlands, they may increase breeding grounds in backwaters created in dry riverbeds, forcing the vector to feed more frequently due to dehydration conditions.

Variations in the life cycle's manifestation inevitably lead to changes in the nature, dispersion and incidence of these diseases. For this reason, it is to be expected that the impact of climate changes, as far as vectors' life cycle is concerned, will manifest with changes in transmission rates of pathogen agents they transmit. Additionally, climate changes modify different environmental characteristics that favour the establishment of vectors in new areas.

Predictions for Spain that indicate more rainy and warm winters, followed by warm and dry summers, propitiate climatic conditions that are favourable to vector establishment and proliferation. Spain is located at a geographical latitude that is appropriate for vectors that already exist to remain, and for other new ones to enter.

Effects on health

As follows, different changes identified for some diseases are specified, selected on the basis of their interest in our country.

In 1964, Spain obtained the official certificate of eradication of Malaria. In the year 2010, the first probably autochthonous case was notified.

The predicted climate change may create scenarios that affect the vector's (Anopheles) development, its geographic distribution and transmissibility (Bueno et al. 2008). Given the presence in Spain of people with parasitemia and vectors capable of transmission, the early detection of entering cases of malaria is fundamental.

Spain forms part of the Leishmaniasis focus, located in the Mediterranean basin. The disease is endemic, present in the better part of the peninsular territory and the Balearic Islands. Presentation patterns in our county include an endemic pattern, presence of cases associated with HIV and immune-deprived patients and epidemic outbreaks, such as the one occurred in 2009.

The predicted increase in temperature may facilitate the presence of vectors (phlebotomines) in all of the territory, increase their activity period and bring about a considerable increase of population densities in areas where they are already present (Gálvez et al. 2011).

Evidence suggests that climatic variables would be on a second level; there would be a series of factors that appear to be much more relevant, such as the appearance of resistant strains to current treatments, the greatest incidence in poor population sectors, an increase in tourism toward endemic areas and insufficient epidemiological vigilance that leads to underestimating the disease and lack of awareness as to the true number of those infected by the parasite.

The group of vector-borne viral diseases includes some of the most relevant in our country, from an epidemiological point of view. All of them are transmitted by mosquitos, except for the Tuscan virus, which is transmitted by phlebotomines.

Vectors that transmit the Dengue Virus, a disease whose world-wide incidence has spectacularly increased over the last decades, is now making Europe face the possibility of autochthonous outbreaks, due to the proven presence of vectors able to transmit the virus. The expansion of mosquitos belonging to the Aedes genus, mainly *Ae. aegypti* and *Ae. Albopictus*, are a short and long-term risk for public health in Europe, although for the time being, it is low. No cases of local Dengue transmission have been documented in Spain, but the risk is far from negligible given the present characteristics, appropriate for transmission.

The cases of Chikungunya Fever detected in Europe in 2010, brought about by an alpha virus transmitted by Aedes genus mosquitos, have raised the alert as to the possible risk of this virus extending beyond customary endemic zones, due to the increase in international travels, the return of immigrants to their places of origin and the importation of the virus to areas where competent vectors (Aedes) exist.

Currently, the West Nile Virus is the most extended arbovirus in the world, and is especially transmitted by Culex genus mosquitos. Over the last decades, this has taken on greater importance, due to its surprising capacity to invade new geographical areas, on numerous occasions causing epidemic outbreaks of great virulence. The Mediterranean basin and the south of the Peninsula particularly, which welcome migrating birds from Africa, are high-risk areas for transmission. An example of this is found in the equine animal epizootic disease that took place in September 2010, in the province of Cádiz.

As far as the Rift Valley Fever, a viral (*phlebovirus*) disease transmitted by mosquitos (Aedes), is concerned, there is no evidence of cases up until now on continental Europe, neither autochthonous nor imported, although the existence of mosquitos that could act as vectors has been confirmed.

The Usutu Virus, a flavi virus transmitted to human beings through Culex mosquito bites, is African in origin, was introduced into Europe and may become a resident pathogen on this continent.

Lastly, regarding the Tuscan Virus, *phlebovirus* transmitted by phlebotomines, its capability to infect dogs and cats has been demonstrated in Spain. Its circulation in the Mediterranean Basin and correspondence between the geographic distribution of the cases and the vector has been contrasted.

Climate change's impact on diseases transmitted by ticks and mites, and the impact on themselves, depends on the species considered and the pathogens they can transmit. According to the different climate scenarios predicted (milder temperatures and dryer settings), determined tick and mite species may have a decreased extension of ideal habitat in Spain, while it may considerably increase for others.

In Spain, the most important diseases transmitted by these arthropods are Lyme borreliosis and boutonneuse fever. The former has recently increased in incidence in some European regions. This may be related to a milder climate, although no clear association has been concluded.

In our country, the predicted climate change will probably make this tick disappear. As far as the boutonneuse fever is concerned, countries in the Mediterranean Basin, including Spain, have reported an increase in incidence. If one considers that the transmitting tick (*R. sanguineus*) has a great adaptive capacity, and that its transmission rate is sky-rocketing during the warmer months in more arid areas, it may be reasonably deduced that the predicted climatic trend would prolong the transmission period.

Finally, the Crimean-Congo haemorrhagic fever is given attention in Europe, due to its distribution and gravity. In our country, where no cases have been recorded yet, three risk factors stand out: the existence of an appropriate climate, dense populations of the transmitting tick, and appropriate hosts for intermediate stages.

Regarding diseases transmitted by rodents, both the wild rodent population and the possibility of contact between a rodent and a human being in urban areas are highly influenced by environmental changes. Years of draught may decrease the number of natural rodent predators, and rains would increase the available food (seeds, nuts, insects). In Europe, the most important disease transmitted by rodents is the Hanta virus, the Puumala being the most frequently implicated.

Vulnerability

The temperature increase in Europe over the past decade was not uniform, since the greatest increase was observed in winter and toward the north of the continent. This fact may influence the elevated vector mortality rate in winter, acting as a population regulator in said areas. However, Spain is far from this buffer effect. Additionally, predictions from change in our country would propitiate favourable conditions for the establishment and proliferation of vectors that would determine a risk of importation and installation of tropical and sub-tropical vectors, adapted to surviving in those climate types.

On the other hand, other factors of a socio-economic nature, such as the increase in international travels, tourism and worldwide commerce, and migratory flows, increase the risk of accidentally introducing pathogens and vectors. However, the aforementioned must be conjugated with other factors, such as the massive and simultaneous afflux of animal or human reservoirs, and the deterioration of socio-sanitary conditions and public health for the establishment of endemic areas.

Main uncertainties and lines of work

Although it is known that climatic variables are the cause of the presence or absence of the aforementioned vectors, it is also true that there are uncertainties regarding the complete scenario formed by vegetation, landscape, animals, and human customs and lifestyles; in other words, in addition to the climate change, there are many factors that may influence the epidemiology of these diseases (Sutherst 2004).

As of now, we have been unable to unequivocally prove that the climate change over the past decades has increased the global risk of transmission of diseases transmitted by arthropods, although there is enough scientific evidence to suspect that this is so.

Recognising that climate by itself is not sufficient cause for endemic focus instauration in Spain, but it is a requisite, the following lines of work are proposed:

- To study the population dynamic in depth of vectors and the processes that rule their life cycles in nature.
- To make progress in studying the health consequences of the climate change, and research the prevalence of certain diseases with seroprevalence studies on at-risk populations.
- To establish proactive epidemiological surveillance in areas where transmission is detected to identify risk factors and create explanatory transmission models.
- To guarantee the capacity of reference laboratories and clinics, and to train health professionals in medical entomology.

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